NORTH CAROLINA
DIVISION OF HIGHWAYS

# GUIDELINES FOR DRAINAGE STUDIES AND HYDRAULIC DESIGN

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1999

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I. INTRODUCTION

This document provides guidance in the methods, procedures, policies, and criteria that must be followed, and the information that is to be developed during a drainage study and hydraulic design. It is not intended to be an all inclusive document on the practice of hydraulic engineering, and the designer must reference other materials and use good judgment in its application to ensure that the design is complete and appropriate for the site. The AASHTO Highway Drainage Guidelines (1)and Model Drainage Manual (2)are recommended as primary references for drainage design.

The engineer is encouraged to apply ingenuity and consider new and differing concepts and procedures in the design process. However, all specified methods, procedures and criteria presented in this guideline must be followed unless approval for variance is given by the State Hydraulics Engineer or his delegated representative.

All referenced design forms, reports and check lists are to be completed and included with the Hydraulics Design Package. The Hydraulic Design Documentation Summary Sheet (Appendix Item A) is to front the design package and must include the seal of the engineer performing or directly responsible for the work. All Bridge and Culvert Survey and Hydraulic Design Reports will be individually sealed by the responsible engineer.

Additional documents required for implementation of procedures, or suggested as further informational resources, are noted as references within the guideline text and listed in the reference section.

## II. GENERAL DRAINAGE POLICIES AND PRACTICES

North Carolina long adhered to the Civil Law Rule in regard to surface water drainage. This rule obligates owners of lower land to receive the natural flow of surface water from higher lands. It subjects a landowner to liability whenever he interferes with the natural flow of surface waters to the detriment of another in the use and enjoyment of his land. Since almost any use of land involves some change in drainage and water flow, a strict application of the civil law principles was impracticable in a developing society. Thus, a more moderate application of this rule to allow a landowner reasonable use of his property evolved.

The North Carolina Supreme Court formally adopted the Rule of Reasonable Use with respect to surface water drainage and abandoned the Civil Law Rule (Pendergrast V. Aiken) in August 1977. The adopted Reasonable Use Rule allows each landowner to make reasonable use of his land even though by doing so, he alters in some way the flow of surface water thereby harming other landowners, liability being incurred only when this harmful interference is found to be unreasonable and causes substantial damage.

There are still some unanswered questions in the application of the adopted Reasonable Use Rule to specific areas of State agency activities. However, the rule is in line with the realities of modern life and will provide just, fair and consistent treatment. Therefore, the policies and practices of the Division of Highways in regard to surface drainage matters follow this rule.

### ENGINEER’S RESPONSIBILITY

The Reasonable Use Rule places responsibility on the "landowner" to make reasonable use of his land. While "reasonable use" is open for interpretation on a case by case basis, it would certainly infer from an engineering standpoint that provisions for, and treatments of, surface waters on the property are made in accordance with sound, reasonable and acceptable engineering practices. Therefore, the Engineer must see that these principles are reflected in the design process.

The rule also states that liability incurs only when harmful interference with the surface water is found to be unreasonable and causes substantial damage. Therefore, it is incumbent on the Engineer to evaluate the potential effects of surface water activities on both up and downstream properties and to include provision in the design to hold these effects to reasonable levels.

These types of engineering practices, considerations and their proper documentation are contained in these Highway Drainage Guidelines, as well as in other referenced materials.

The following are general drainage policies and practices of the North Carolina Division of Highways involving both design and maintenance activities.

## AUGMENTATION, ACCELERATION

Development of property can cause an increase in the quantity and peak rate of flow by increasing impervious areas and providing more hydraulically efficient channels and overland flow. It is the policy of the Division of Highways to develop and make reason- able use of its lands and rights-of-way through sound, reasonable and acceptable engineering practices and to deny responsibility for augmented or accelerated flow caused by its improvements unless determined to cause unreasonable and substantial damages. It is likewise the policy of the Division of Highways to expect this same practice and acceptance of responsibility by other property owners and those engaged in the development of these properties.

## DIVERSIONS

Diversions are defined as the act of altering the path of surface waters from one drainage outlet to another. It is the policy of the Division of Highways to design and maintain its road systems, so that no diversions are created thereby, insofar as is practicable from good engineering practice.

Any person(s) desiring to create a diversion into any highway rights-of-way shall do so only after receiving written permission. This permission will be granted only after it has been determined that the additional flow can be properly handled without damage to the highway, that the cost for any required adjustments to the highway system will be borne by the requester, and that appropriate consideration and measures have been taken to indemnify and save harmless the Division of Highways from potential downstream damage claims. It is Division of Highways policy not to become a party to diversions unless refusal would create a considerable and real hardship to the requesting party.

## IMPROVEMENTS AND MAINTENANCE OF DRAINAGE WITHIN THE RIGHT-OF-WAY

Drainage structures and ditches shall be kept open and maintained at a functioning level such that they do not present an unreasonable level of damage potential for the highway or adjacent properties.

Where the elevation of the flow-line of an existing culvert under a highway is not low enough to adequately provide for natural drainage, the Division of Highways will assume full responsibility for lowering the culvert or otherwise provide needed improvement.

Where a requested culvert invert adjustment is a result of a property owner lowering the flow-line of the inlet and outlet ditch in order to improve drainage of his property, the following considerations shall be given to the action taken:

- The lowered drain must have a reasonable expectancy of being functional and maintainable.
- Division of Highways participation (up to full cost) must be based on benefit gained by the roadway drainage system as a result of the lowering.
- Where the new installation is of doubtful, or no benefit to highway drainage, the requesting party must bear the entire cost of installation.

Where the size of an existing highway culvert is determined to be of unacceptable adequacy in regard to the roadway system functioning as a result of a general overall development of the watershed, it is the Division of Highways' responsibility to replace the structure or otherwise take appropriate action.

Where this same culvert inadequacy is the result of a single action or development, it is felt to fall within the realm of "unreasonable and substantially damaging" under the State adopted drainage ruling. Therefore, the party responsible for the action or development should bear the cost of replacement.

Where a new culvert crossing is requested, if the culvert is required for proper highway drainage or sufficient benefits to the highway drainage system would occur, the full cost will be borne by the Division of Highways providing there is no diversion of flow involved. Where the new installation is of doubtful or no benefit to highway drainage, the property owner will bear the entire cost. When both parties receive benefit, a joint effort may be negotiated.

Established culvert crossings will be maintained and requests to eliminate any culvert should have the approval of the State Hydraulics Engineer.

When new private drives are constructed entering the highway, the property owner can furnish, delivered to the site, the amount, type and size pipe designated by the Division of Highways, to be installed by maintenance forces.

No alteration, attachment, extension, nor addition of appurtenance to any culvert shall be allowed on highway rights-of- way without written permission.

## IMPROVEMENTS AND MAINTENANCE OF DRAINAGE OUTSIDE THE RIGHT-OF-WAY

While it is the responsibility of the Division of Highways to provide for adequate drainage for constructing and maintaining the State Highway System, it is not its policy nor responsibility to provide improved drainage for the general area traversed by such roads, unless incidental to the drainage of the road or highway itself. Drainage involvement outside the highway rights-of-way is limited to two general areas of justification:

- Sufficient benefit could be gained by such action to warrant the cost. These benefits would be in such areas as reduction in roadway flood frequency or extent, facilitation of maintenance, or a reduction in potential damages.

- Work is required to correct a problem or condition created by some action of the Division of Highways.

It is not the responsibility of the Division of Highways to eliminate flooding on private property that is not attributable to acts of the agency or its representative.

In general, outlet ditches will be maintained for a sufficient distance below the road to provide adequate drainage therefore. On large outlets serving considerable areas outside the right-of-way, the maintenance should be done on a cooperative basis, with the benefited properties bearing their proportionate share. Shares will, in general, be based on proportioning of runoff from the areas served by the outlet.

It is not the policy of the Division of Highways to pipe inlet or outlet drains, natural or artificial, outside the right- of-way, which existed as open drains prior to existence of the highway. Where the property owner wishes to enclose an inlet or outlet, the Division of Highways may install the pipe adjacent to the right-of-way if justified by reason of reduced maintenance, safety or aesthetics if the pipe is furnished at the site by the property owner. This does not apply to the development of commercial property.

## OBSTRUCTIONS

It is the policy of the Division of Highways that when a drain is blocked below the highway, which is detrimental to highway drainage, if from natural causes, the Division of Highways will take necessary measures to remove the block or obstruction. Where the block is caused by wrongful acts of others, it is the policy of the Division of Highways to take whatever recourse deemed advisable and necessary to cause the party responsible to remove the block. Where a block occurs downstream of a highway, whether natural or artificial, and is of no consequence to the Division of Highways, it is the policy to remain neutral in causing its removal.

State Statute (G. S. 136-92) provides that anyone obstructing any drains along or leading from any public road is guilty of a misdemeanor.

## DRAINAGE EASEMENTS

Where runoff is discharged from the right of way at a point where there is no natural drain or existing ditch, a permanent drainage easement is required to allow construction of a ditch or channel to convey the discharge to an acceptable natural outlet. When the discharge is into a natural drain or existing ditch and the increase in flow would exceed the capacity or otherwise create a problem, a temporary drainage easement can be obtained to allow enlarging or otherwise improving the drain to a point where the increase discharge will not cause damage.

It is generally preferable that any structural feature such as a drop inlet, catch basin, or pipe-end be contained within a permanent easement.

## DAMS AND IMPOUNDMENTS

It is the policy of the Division of Highways to discourage the location of roadways on dams due to the increase in potential for long term maintenance and replacement cost. In those instances where a defined advantage may be gained or a substantial savings in funds may be realized, the use of a dam for a roadway may be favorably considered.

Where it is determined that a dam will be utilized as a roadway the following criteria must be met:

- It must have approval certification from DENR pursuant to the State Dam Safety Law of 1967, when applicable.
- All pertinent data regarding the design of the embankment and impoundment structure must be presented to the DOT for review.
- Top section of the dam must be equal to the approach roadway section width (shoulder to shoulder) plus a minimum of 4 feet.
- Guardrail is required on the impoundment side of the roadway.
- The spillway will be designed to provide a minimum freeboard at the roadway shoulder of 2 feet for a 50-year impoundment level.
- Means of draining the lake completely will be provided.

Design acceptance or approval by the Division of Highways is limited to the use of the dam as a roadway only, and is in no way intended as approval of the embankment as an impoundment structure.

Responsibility incurred by the Division of Highways when a section of roadway crosses a dam is accepted as a part of the state maintenance system is limited to maintenance of the roadway for highway purposes from shoulder to shoulder only. Responsibility for the impoundment, any damage that may result there from, and maintenance of the embankment or appurtenances as may be required to preserve its’ integrity as an impoundment structure shall remain with the owner of the impoundment. Any maintenance work will be subject to the provisions of G.S 136-93.

Impoundment of water on highway rights-of-way may be allowed under the following criteria:

- The impoundment does not adversely affect the rights-of-way for highway purposes.
- Adjustments as required (ex. flattening slopes, rip rap slope protection, structure modifications, etc.) shall be the responsibility of the encroaching party.

## SUBDIVISION STREETS

When roads and streets built by others are accepted onto the state system for maintenance, responsibility for the drainage system, discharge pattern and outlet locations is as it exist at the time of acceptance and is limited to the rights-of-way.

Information on design, review and approval requirements is provided in the reference (3),“Subdivision Roads- Minimum Construction Standards”

## III. PRE-DESIGN STUDY AND REPORT

Prior to commencing detailed design or field studies, the project is to be reviewed in general to familiarize the engineer with the project requirements. Field and office data are to be collected and reviewed to determine what additional information is required during the field reconnaissance and survey stage. At this time, local highway maintenance personnel are to be contacted for their input on problem areas and other pertinent information. Specific methods, procedures and criteria are also addressed at this stage. Unit design engineers are to complete this phase with a "pre-design review meeting" with their project engineer. Private engineering firms are to hold this meeting with the unit's project engineer responsible for consultant coordination. The unit or private project engineer is to prepare a draft listing of topics and information for discussion at the meeting. He is to add to this documentation, actions and decisions agreed to at the review meeting resulting in a summary document for inclusion in the final project report. The section of the "Check List for Drainage Study and Hydraulic Design" - Appendix Item B, identified as Prior to_Field Survey is to be completed and approved at this stage.

## IV. FIELD RECONNAISSANCE AND SURVEY

The Location and Survey Unit is to provide special survey data required by the hydraulic engineer for the design study. The type and presentation format of this data is provided in the Locations Units' "Hydraulic Survey Guidelines". For specialty or unusual projects the Location Engineer will coordinate with the Hydraulics Unit to identify data requirements during the initial stage of the survey. The hydraulics engineer will supplement the location data with survey and informational data obtained during his field reconnaissance and site visit. Review of the project in the field prior to commencing detailed design is a requirement of the engineer with primary responsibility for the drainage study. The purpose of this field trip in addition to obtaining supplemental survey data is to:

- visually acquaint the designer with conditions and constraints of the site
- verify data obtained from other sources
- identify ponds, lakes, reservoirs and other storage areas which affect discharge rates
- review existing drainage features and obtain information on performance
- review potential outlet channels for performance and adequacy
- identify sediment sensitive areas such as lakes, ponds, and developed stream areas
- review contributing watershed characteristics
- review and obtain design information on environmental areas of concern such as wetlands and special fishery streams (State GIS mapping is a good resource)
- obtain details of size, location, length, material type and condition of existing drainage structures. When existing box culverts are to be extended, top slab and center wall thickness must be obtained.
- obtain historical flood and other stream flow information such as:(also see channel data collection, Section IX)
    - maximum and other large flood levels at as well as up and down stream of the study site
    - dates of these occurrences
    - very frequent flooding levels (examples: annual, 2 year, 5 year)
    - channel scour and instability
    - drift potential, size and quantity
    - conveyance of existing crossings including roadway overtopping, damage and time of closure

- descriptive photographs of site

- examples of additional survey data and supplemental topographical information:
    - elevations of flooding
    - elevation of up and down stream features which could control the design such as buildings, roads, yards, fields and other drainage structures
    - stream bed elevations a sufficient distance up and down stream to establish local stream gradient
    - floodplain and channel cross-sections for backwater analysis and channel realignments
    - development and cover in floodplain for determination of flow resistance and distribution.
    - General description of stream bed and bank materials (clay, silt, sand, gravel, cobble, rock). If extensive rock is visible explore extent by probing on culvert size streams for possible footing.
    - locate areas where berm ditches are needed.

- Additionally for urban sections:
    - Locate and obtain elevations of low areas back of proposed curb for special pickups
    - Locate small inflow systems such as roof and basement drains.

- Review and obtain the following type information for use in bridge scour analysis:
    - Description of floodplain and channel material. If sand or silt, is it fine, medium or coarse?
    - Observe existing structure for evidence of scour and condition around footings and supports.
    - Verify or obtain channel cross-sections under bridge and at locations at least two bridge lengths up and down stream.
    - Elevation and location of deepest point in channel.
    - If visible, note type and condition of existing foundation.

- Review site conditions and obtain precise limits and classification of wetlands and jurisdictional streams for permit application.

All pertinent data and facts gathered through this field reconnaissance and survey are to be documented on work plans, field notes or other forms suitable for submittal with the final project report. The section of the "Check List for Drainage Study and Hydraulic Design" - Appendix Item B, identified as field study is to be completed prior to completion of the field study.

## V. DRAINAGE PLANS

The development of a drainage plan as described in this section is directed toward hard copy drawings and a non-electronic process of plan development and data supply. It is now common to utilize electronically gathered data supplied on terrain models, CADD drafting and automated design packages such as GEOPAK. Even with these advanced tools available to the engineer the basic drainage plan development concept is still applicable. The engineer is directed to consider this in applying the following procedure.

A copy of the project preliminary roadway plans with the proposed roadway section and construction limits noted is to be used as work plans to develop a pencil sketch type layout of the proposed drainage features. The sequence of development of these plans should be as follows:

(1) Confirm and add as necessary all existing drainage features (structure type, size, elevations).

(2) Note all existing drainage divides, flow directions, ditches, channels, etc.

(3) Confirm and add information addressing utilities that may affect drainage features.

(4) Plot any special ditches or other topographical features identified during field surveys and not included on the plans.

(5) Make notes of design controls identified during data collection and field survey stage.

(6) Determine and evaluate the patterns of surface flow as affected and developed by the project construction. (Note flow direction and concentrations as needed for clarity in <u>red</u>).

(7) Develop a scheme and layout of drainage features (bridges, box culverts, pipes, storm drainage systems, ditches, channels, etc.) to properly convey surface flow within and adjacent to the project. Note these features on the plans in <u>red</u>.

(8) Utilizing procedures presented in the following section of these guidelines, perform the design studies required to detail each drainage feature (type, size, location, material, etc.).

(9) Documentation of the design detail of each individual feature will be provided as directed in the related section of the guideline. A short summary of information relating to each feature shall be noted on these work plans and consist of the following as a minimum:

- location by station, skew or other descriptive detail
- type, size and material
- elevations (invert, grade, etc.)
- drainage area
- design discharge and elevation
- base discharge and elevation
- overtopping discharge and elevation

(10) Plot storm drainage system profiles including:

- pipe and inlet inverts
- utility crossings
- hydraulic grade line (water surface profile)

(11) Note all special channel and ditch detailing including special grades and permanent lining requirements.

## VI. HYDROLOGY

The hydrological analysis phase involves the determination of discharge rates and/or volumes of runoff that the drainage facilities will be required to convey or control. Many hydrological methods are available and most can be appropriately and effectively used under proper control and application. Particular methods recommended for highway drainage studies and circumstances for their use are listed below. When the site involves a FEMA flood study area, discharge methods and values provided in the report will take precedent over these methods for determining compliance with the regulation. The results from any hydrologic procedure should be compared to historical site information and adjustments made in the values estimated or procedure used when deemed appropriate. The designer must also consider potential future land use changes within a watershed over the life of a roadway structure and include this effect when estimating design discharges.

### METHODS

Rural Watersheds - Peak Discharge

$\geq$ 1 $mi^2$ The procedures and values presented in U. S. Geological Survey, Water Resources Investigation Report 99-4114 (4), shall apply.

$\leq$ 1$mi^2$ The hydrological procedure and charts presented in Appendix C, N. C. Division of Highways Hydrologic Charts-1973,(C200.1 and C200.2) shall be used.

Urban Watersheds - Peak Discharges

$\leq$ 10 acres If watershed is primarily composed of pavement, grassed shoulders and slopes, and/or other mixed surface type runoff, use rational formula for discharge determination. If predominately residential type development with natural drainage channels, use Highway Charts C200.1 and C200.3.

$\geq$ 10 acres $\leq$ 100 Use Highway drainage charts (C200.1 and C200.3). If areas have greater than 50% impervious cover and/or extensive storm drainage systems, a special procedure such as routing is recommended. The HEC-1 and NRCS, TR-20 are widely used routing procedures. Determination of specific sites for special study and selection of a design procedure must be approved by the Reviewing Engineer. This item should be addressed in the pre-design meeting.

$\geq$ 100 acres Use the procedure presented in U.S.

Investigation Geological Survey Water Resource Report 96-4084(5).

Volume of Flow — The procedures presented in U.S. Geological Survey Report 96-4085(6) for developing a runoff hydrograph can be utilized to determine flow volume. For estimating purposes or minor impoundment (<1 acre-foot) a simple triangular hydrograph as described later in this chapter can be used.

## APPLICATION GUIDANCE

"U.S.G.S. Water Resources Investigations Report 99-4114"

Two regional analysis methods are presented in this report. The first employs the traditional regional regression equations that are presented in Table 5, page 11. The second is the region-of-influence method that must be developed through the use of a computer software program due to the complexity of the computations. This program provides both the regional regression and region-of-influence solutions, allowing the engineer to compare and select a design value. This computer software package is available at the NC USGS home page on the internet. For gaged sites, the discharge estimate is to be determined by weighting the regional and station estimates (See Equation 7, Page 15). For sites on gaged stream and having a drainage area within 50% (0.5 to 1.5)of the gage site, the discharge estimate is to be transferred from the gage in accordance to Equation 8 and 9, Page 16.

"Highway Charts”(Appendix C)

The rural areas charts C200.1 and C200.2 are to be used within the limits previously noted. The procedure for use is as follows:

(1) From Chart C200.1 determine the hydrologic contour by location of the structure site. Interpolate to 0.5 contour interval.

(2) Determine: Drainage area (acres or $mi^2$)
Watershed shape factor($A/L^2$)
Percent forested cover

(3) Enter chart C200.2 with drainage area and hydrological contour and read discharge.

(4) For discharges other than Q50, apply frequency adjustment factors shown on chart.

(5) Enter charts C200.4 and C200.5 to determine adjustment factors to be applied to above values for percent forested cover and watershed shape.

NOTE: The forested cover value can be used to reduce discharge only when the watershed is mountainous, wetlands, or a designated preserve area where clearing is very unlikely.

The multiple of the two adjustment factors cannot exceed the limits of 0.7 and 1.5.

The urban chart, C200.3 is to be used within the limitations previously noted. Procedure for use is as follows:

(1) From chart C200.1 determine the hydraulic contour to the nearest 0.5 interval.

(2) Determine the type and relative density of development. This should be a projection of conditions based on potential future development over the life of the structure. The development types as noted on the chart are:

- Residential-High Type; This is suburban type development with lots sizes > 0.5 acres
- Average Development; Small lots < 0.5 acres or mixture of residential and some small business
- Large Area Full Business; Area > 75 acres, no more than 50% impervious cover or extensive storm drainage systems
- Small Area Full Business; Area < 75 acres no more than 50% impervious cover or extensive storm drainage systems

(3) Enter chart C200.3 with drainage area and hydraulic contour and read discharge.

(4) Apply appropriate adjustment factor for development type.

(5) For discharges other than Q10, apply frequency adjustment factors shown on chart.

"Rational Formula"

The rational formula estimates the peak rate of runoff (Q) in $ft^3/s$ as a function of drainage area (A), in acres runoff coefficient (C), and mean rainfall intensity (I) in in/h for a duration equal to the time of concentration ($t_c$), the time required for water to flow from the most hydraulically remote point of the basin to the location of analysis.

$$Q = CIA$$

Use limitations are noted previously in the guidelines. For expanded discussion of the rational formula see "FHWA, Hydraulic Engineering Circular No. 22"(7)

Some specific criteria are:

A = 10 +/- acres maximum (When the watershed for a continuous storm drain system is greater than the suggested maximum, it is acceptable to exceed this value)

I = Use highway charts C200.7, C200.8,C200.9. (Appendix C).Interpolate between cities for other points. The Hydrain program will provide values based on latitude and longitude location.

C = Use a weighted value =  CiAi/A

Table 4-2 provides some often used values:

| **TABLE 4-2** | |
|---|---|
| **TYPE OF SURFACE** | **C** |
| Pavement | 0.7 - 0.9 |
| Gravel surfaces | 0.4 - 0.6 |
| Grassed, steep slopes | 0.3 - 0.4 |
| Grassed, flat slopes | 0.2 - 0.3 |
| Woods | 0.1 - 0.2 |

Time of concentration ($t_c$) - Use Kinematics wave equation for overland flow time. See page 3-8, Hydraulic Engineering Circular No.22,(6). Minimum $t_c$ - 10 min.

USGS Report 964084 “Estimation of Flood-Frequency Characteristics of Small Urban Streams in North Carolina”

Urban regression equations are provided on page 14 of this reference. Details are provided on page 17 for use of the equations.

"Snyders Synthetic Unit Hydrograph"

This procedure can be utilized to develop a design hydrograph associated with a peak flow. It can be performed with or without precipitation and surface runoff data. It provides a graphical depiction of runoff as a function of time as well as an estimate of runoff volume. FHWA, Hydraulic Design Series No. 2(8) and No. 22(7), are reference sources for detailed direction in this procedure. The Hydrain computer program also includes this design alternate.

“Triangular Hydrograph Storage Estimate Method”

Develop inflow:

1. Determine peak discharge Qp
2. Estimate time of concentration Tc
3. Calculate time to peak Tc + 0.6Tc(hrs.) Tp
4. Calculate total time Tp x 3 T
5. Calculate average discharge 0.33Qp Qa
6. Calculate total runoff volume Qa/12 x T=(acre-feet) Qt

Determine outflow:

1. Determine available storage (acre-feet) Qs
2. Calculate net runoff Qt - Qs Qn
3. Calculate average outflow Qn x 12/T= (cfs) Qao
4. Calculate peak outflow 2 x Qao Qpo

ANALYSIS PROCESS

The overall hydrologic analysis for a project begins with review and extrapolation of pertinent information from data sources identified during the pre-design study. Final determination of sources of watershed areas and base mapping for drainage area delineation are also made at this time. Primary resources for this information are:

- U.S.G.S. and T.V.A. quadrangle mapping
- U.S.G.S. open file report 83-211 "Drainage Areas of Selected sites on Streams in North Carolina"
- Photogrammetric contour mapping
- Aerial photography
- Special studies (Corps, TVA, FEMA)
- Field reconnaissance (This is required for most non-riverine drainage areas in the coastal plain as well as any small watersheds in other areas.)

The selection of a "design discharge" for a drainage feature is a risk based assessment process involving the evaluation of a range of flood magnitudes for such factors as potential damages, costs, traffic service, environmental impact, and flood plain management criteria, to determine an appropriate and acceptable structure for each site. One specific criterion on which the design is evaluated and generally referred to as the "design discharge" is the flood level and frequency which results in inundation of the travelway. Table 4-3 relates desirable minimum levels of protection from travelway inundation to roadway classification. Variation from these minimum design levels must be justified through the assessment process and appropriately documented. When roadway overtopping is not involved, the "design discharge" will be the level of flood used for establishing freeboard and/or backwater limitations.

| TABLE 4-3 | |
|---|---|
| **ROADWAY CLASSIFICATION** | **FREQUENCY** |
| Interstate (I) | 50 year |
| Primary (US & NC) | 50 year |
| Secondary (Major, City thoroughfare) | 50 year |
| Secondary | 25 year |

The hydrologic analysis process for a specific drainage feature is accomplished as an integral part of the hydraulic sizing and performance analysis. Specific discharge criteria and computational needs are addressed in further sections of this guideline for each particular drainage feature. Documentation of the hydrologic data is included with the hydraulic design.

The following general guidance shall be used to determine when it is appropriate to consider the overtopping flood and the limits used in defining the data. This must be applied with good judgment and considered on the particular merits of each crossing analysis.

(1) Where overtopping is not practicable and would require flood magnitude greater than state of the art capability to estimate frequency (500+ year flood), a statement similar to the following should be noted on the survey report "overtopping flood is greater than 500+ year event".

(2) An approximate frequency of occurrence must be established for the overtopping discharge. The following frequency designation will be used:

(a) If within 5% of the 200 or 500-year estimated discharge, list as 200-year +/- or 500-year +/-.

(b) If greater than 100-year flood but not within 5% of 200-year, list as 100-year +.

(c) If greater than 5% of the 200-year but not within 5% of the 500-year, list as 200-year +.

(d) If greater than 5% of the 500-year, list as 500-year +.

## VII. BRIDGE CROSSINGS

The design of a stream crossing requires a comprehensive engineering approach that involves data collection, hydrologic analysis, formulation of alternatives, evaluation and selection of the "best" alternative according to established criteria, and documentation of the final design. The design process provided herein will not attempt to address all situations or all areas of knowledge and experience the engineer should possess to be proficient in crossing design. It is strongly recommend that the engineer reference and study the bridge crossing chapter of the "AASHTO-Highway Drainage Guidelines" (1), and the FHWA floodplain policy statement in FAP-Guide, 23 CFR 650A (9). The design procedure presented herein will insure a systematic process that will adequately address most crossing situations. It will also help to identify conditions and situations requiring special study and/or consideration.

Design and analysis of stream crossings in the coastal region that are subject to the effects of tidal flows and storm surge follow a similar procedure to that outlined for riverine crossings. However, there are major differences in the hydrologic and hydraulic analysis phases. The engineer is referenced to the basic tidal prism procedure contained in HEC-18(12), as well as more detailed one and two dimensional tidal crossing models presented in, *Tidal Hydraulic Modeling for Bridges(13).*

(1) DATA COLLECTION

Information gathered during the pre-design study and field survey is to be assembled for the study site. This process will include:

(a) Review of the preliminary design and assessment report (Appendix D)

(b) Plotting of a plan and profile view of the topographical features for the crossing on the Bridge Survey and Hydraulic Design Report (Appendix E)

The drawing scale shall be 1 in.= 50 ft. horizontal,1 in.= 10 ft. vertical with existing manmade features shown with dashed lines .A larger sheet may be used if required for wide floodplain. It must be trimmed and folded to fit within the Survey Report.

Information to be included on the profile view:

- Centerline profile of the floodplain
- Historical flood data (high water elevations,date of occurrence, and estimated frequency)

- Show existing features (utilities, drainage structures, and crown grade profile of existing highway)

- control elevations such as existing buildings
- Water surface elevation at date of survey and "normal" water surface elevation

Information to be shown on plan view:

- Natural features (limits of floodplain, stream channel showing base and top of bank, type of vegetative cover in floodplain, stream classification)
- Existing man-made features in floodplain (buildings, houses, highways, utilities, etc.)

(2) HYDROLOGIC ANALYSIS

This phase involves the development of a number of discharges on which the performance of alternate designs will be evaluated. This entails:

(a) Determination of a drainage area for the site

(b) Developing discharge quantities for a range of floods to be studied. This shall include as a minimum:

$Q_2$, $Q_{10}$, $Q_{25}$, $Q_{50}$, $Q_{100}$, Q-overtopping (existing roadway), Q-overtopping (proposed roadway)

(c) If a crossing is in a FEMA Regulated Flood Insurance Program site where a detail study has been performed, the study discharges will be used to evaluate conformity of the project to flood zone regulations. If an error is found in the FEMA hydrological data or if there is considerable disagreement in the data and results from standard hydrological procedures presented in this guideline, a specific course of action shall be developed and approved by the Reviewing Engineer.

(d) Document the hydrologic analysis portion of the Bridge Survey and Hydraulic Design Reports.

(3) FORMULATION OF ALTERNATIVES

This and the next phase, Alternative Evaluation and Selection, is generally an iterative process through which a hydraulic analysis is performed for one or more alternatives, the results are evaluated, adjustments are made and further alternatives developed until the "best" alternative is selected. This hydraulic analysis of alternatives will be accomplished as follows:

(a) The Corps of Engineers HEC-RAS Step-backwater Analysis Program is recommended for the stream reach study. An exception is to be made for utilization of the HEC-2 when an existing detailed flood study crossing is involved. FHWA-WSPRO is another acceptable model.

(b) A minimum of three cross-sections shall be used (one each up and downstream and one at the crossing). Additional sections should be used when site conditions warrant.

(c) A run of the model with the selected discharge shall be made under existing conditions and a comparison made to at least one historical occurrence.

(d) Adjustment shall be made to calibrate the model to a "best" or "reasonable" fit to the historical data.

(e) FHWA "Guideline for Selecting Manning's Roughness Coefficients for Channels and Flood Plains" (9), should be referenced for roughness factor selection.

(f) A profile plot of the adjusted model including the historical data shall be provided.

(g) Alternate structures and grade configurations can now be entered for hydraulic output development.

(4) EVALUATION AND SELECTION

The selection of a "best" alternative is accomplished by comparison of the study results and considerations to acceptable limitations and controls. These limitations are prescribed by general and specific criteria.

General criteria on which the design alternatives must be judged are:

- Backwater will not significantly increase flood damage to property upstream of the crossing.
- Velocities through the structure(s) will not damage the highway facility or unduly increase damages to adjacent property.
- Existing flow distribution is maintained to the extent practicable.
- Level of traffic service is compatible with that commonly expected of the class of highway and projected traffic volumes.
- Minimal disruption of ecosystems and values unique to the floodplain and stream.
- Cost for construction, maintenance and operation,

including probable repair and reconstruction, and potential liabilities are affordable.

- Pier and abutment location, spacing, and orientation are such to minimize flow disruption, debris collection and scour.
- Proposal is consistent with the intent of the

standards and criteria of the National Flood Insurance Program.

Specific criteria on which the design alternate must be judged:

(a) Design discharge
This is the specific return period flood that has been established as being an acceptable level for roadway overtopping. When roadway overtopping is not involved, it will be the level of flood used for establishment of freeboard and/or backwater limitations. See Table 4-3, chapter VI, for desirable design discharge standards based on accepted inundation levels relative to roadway classification. Variation from these or other specific standard values must be justified by an assessment process which reflects consideration for risk of damages to the roadway facility and other properties, traffic interruption, environmental impacts and hazard to the public.

(b) Backwater
This is the increase in water surface elevation for a particular flood event measured relative to the normal water surface for this same event at the approach section. For National Flood Insurance Program designated floodplains, the backwater for the 100-year flood shall not exceed 1.0 foot. The normal water surface as it relates to a flood insurance site would include any restriction existing at the time of adoption of the regulation, such as an existing bridge. When a detail study area is involved, no increase in backwater is allowed when the crossing data is entered into the floodway model unless a modification proposal is developed and presented to the community and FEMA for approval. A modification proposal is to be a revision in the floodway boundaries to accommodate the crossing without increasing the 100-year flood elevation above the established floodway elevation.

(c) Minimum length
The bridge ends will be located such that in the profile bridge section a line projection of the spill through slope face provides a minimum of 10 foot setback from any point on the channel bank or bed. Greater setback can be dictated by hydraulic conveyance needs and channel scour predictions.

(d) Freeboard

Provide 2 feet minimum clearance for bridge super-structures above the design flood for primary route structures and secondary crossings of major rivers. 1.0 foot minimum for all other structures. There is no established freeboard for the roadway or other controlling features. However, this can be established as a project specific requirement if a specific need or condition warrants. This or a justified variance from the standard freeboard requirement must be approved by the Reviewing Engineer prior to completion of the design.

(e) Slope Protection
As a minimum class II stone rip rap shall be placed on the spill-through bridge slopes through the waterway opening extending to a point even with the bridge ends. The need for additional slope protection along the roadway fill approaches shall be evaluated on a site by site basis. Concentration, depth and velocity of flow in the overbank are factors to be considered in setting the rip rap limits. As a guide, the following equation can be used. If $V_2$ is considered to be less than a scourable velocity for the proposed fill slope, no further evaluation is necessary.

$$Z = (1 - V_1/V_2)L$$

Where:

$Z$ = Required distance of slope protection

$V_1$ = Average velocity in overbank approach

$V_2$ = Average velocity in bridge opening area adjacent to fill

$L$ = Distance up stream to maximum backwater (bridge length)

The top of the rip rap elevation shall be 1.0 foot above the "design flood" which, for establishing slope protection limits, will not exceed the 50-year event.

(f) Deck Drainage
Standard practices for structural design at this time is to include 6 inch scupper drains at 12 foot centers in all waterway crossing structures. They can be eliminated in areas directly over channel when crossing identified sensitive streams. If review for variance from this standard is requested, the spacing requirement will be based on:

(1) Scupper capacity provided in HEC-21(11)

(2) 4 inches per hour rainfall intensity (maximum drivable)
(3) A minimum consideration of 30% blockage
(4) Maximum gutter spread of 2 feet.

Provision must be made to handle the flow from the bridge deck at all down grade ends. The capacity and adequacy of these drains can also be checked using the procedures of HEC-21(10).

Separation structures will have a very limited number of scuppers (adjacent to the piers). The potential gutter spread along the structure must be determined for acceptability. This acceptable spread is dependent on shoulder or special width provided on a structure, but should not extend into the travel lane of a shoulder approach structure. The fewscupper drains can be ignored in this spread evaluation for separation structures. With the potential quantities of flow from the deck, it is very important to check the adequacy of the end drains and provide recommendations for additional measures when warranted.

(g) Channel Changes
As a general rule, the bridge crossing will be designed to accommodate the natural channel. Channel modification will be considered only when there is no practicable alternative from a cost or functional standpoint. Modification proposals with sufficient supportive data must be presented to the Reviewing Engineer for approval prior to completion of the design.

(h) Scour
An estimate of potential Scour depth is required for all bridge sites. The procedure for this analysis is presented in HEC-18, reference,(12). And HEC-20, reference(14)

(i) Economics
When more than one alternate will satisfy all control factors for a site, the evaluation and selection of a "best" alternate must include an economic analysis to insure that the selected alternate provides the least total cost from a construction, maintenance, and operation standpoint.

(j) Detour bridges
The design process for these structures is also site specific. As general guidance a $Q_5$ design flood provides an acceptable level of risk for potential traffic interruption or damage to the detour. However, potential for damage to other developed properties if overtopping at this level of flood is not provided will warrant further consideration and a possible increase in the structure requirements.

Spanning of the normal flow channel is recommended and scour consideration is limited to local scour at any in channel bents.

(5) DOCUMENTATION OF DESIGN

All information pertinent to the selection of the "best" alternate shall be documented in a manner suitable for review and retention. This will involve:

(a) Completion of the Bridge Survey and Hydraulic Design Report, Appendix E. Sketch proposed structure(s) and roadway grade in plan and profile showing crown grade elevation, super structure, bent locations, limits and elevations of rip rap and any channel modifications.

(b) In addition to the data required on the survey relative to the design, overtopping and base flood, provide in table or performance curve form a depiction of the natural and post-design water surface elevations at the upstream section for the design flood. If at an existing crossing site, include the existing condition as a third listing and plot.

(c) Include scour formula computations on the bridge survey report. Plot estimated depths on profile view.

(d) Provide hard copy summary sheet of computer input and output.

(e) Provide complete computer analysis data files on an IBM compatible floppy disk and include file name on Bridge Survey and Hydraulic Design Report.

(f) When a floodway modification is proposed, supply all documentation required for submittal to FEMA. This will include:

- Completion of the application form for floodway revision request or amendment to the National Flood Insurance Program (NFIP) maps.
- Hydraulic analyses (computer models - input and output) which duplicate the hydraulic analyses used for the effective FIS (baseline model) for the following frequency floods: 10-, 50-, 100- and 500-year floods and the 100-year floodway.
- New/revised hydraulic analyses (computer models - input and output) for existing conditions for the following frequency floods:

10-, 50-, 100-, and 500-year floods and floodway. (This involves adding sections for the crossing site without the structure and for any changes in the floodplain.)

- New/revised hydraulic analyses (computer models - input and output) for proposed conditions for the following frequency floods: 10-, 50-, 100-, and 500-year floods and floodway. (This involves the addition of the crossing features and any proposed floodway changes.)

- Topographic work map with existing and proposed topography showing revised existing and/or proposed 100- and 500-year flood boundaries, 100-year floodway, base flood elevations, cross sections, stream alignment, and road alignment.
- Annotated FIRM and/or Flood Boundary and Floodway Map (FBFM) showing revised existing and/or proposed 100- and 500-year flood boundaries, 100-year floodway, base flood alignment, and corporate limits.
- Annotated FIS flood profile(s) showing revised existing and/or proposed 10-, 50-, 100-, and 500-year flood profiles.
- Annotated FIS Floodway Data Table(s) showing revised existing and/or proposed floodway data.

## VIII. CULVERTS

A culvert is a conduit that conveys flow through the embank- ment. The most commonly used shapes are circular, rectangular, elliptical, pipe arch and arches. They range in size from large multiple barrel box culverts and metal arch structures to single 18 inch pipes. The design process for culverts as well as all drainage structures is much like the bridge crossing in that it involves: data collection, hydrologic analysis, formulation, evaluation and selection of an alternate, and documentation of the design. Some of the larger structures must be analyzed by the same procedures and methods as a bridge crossing. The procedure presented here is summary in nature and is intended for the common box or pipe culvert crossing. The extent of design effort for a particular culvert must be commensurate to its cost and potential risk to the public. The engineer should reference FHWA, Hydraulic Design Series No. 5 (15), for more detailed guidance. He must also reference this document for nomograph charts and tables required for a manual design process.

The forms used for documentation and the information required differ for box and pipe size culverts. Any culvert structure providing conveyance greater than a single 72 inch pipe will follow the design procedure and documentation on the "culvert survey and hydraulic design report" (Appendix F). Smaller culvert design will be documented on a pipe data sheet (Appendix G).

(1) Data Collection

Information gathered during the pre-design study and field survey relative to each particular crossing or all crossings in general is to be assembled. This process will include:

(a) For all box culverts or any other structure that preliminary estimates indicate requiring a total crossing conveyance greater than a single 72 inch pipe, plot a plan and profile view of the stream crossing on the "Culvert Survey and Hydraulic Design Report" (Appendix F). The drawing scale is to be 1 inch = 50 feet horizontal and 1 inch = 10 feet vertical. Existing features are to be in ink with manmade features shown with dashed lines. This information is to be limited to that which is pertinent to the structure sizing and location.

Information to be provided on the profile view:

(1) There are to be two profiles - one along the centerline of the roadway showing the flood plane section and roadway profile both

existing and proposed. The second profile is to be along the centerline of the structure showing the stream bed grade, top of bank and normal water surface profile.

(2) The centerline of the roadway profile should show: ground line, channel base and banks, grade line, water surface elevations (date of survey, normal if different), flood plain limits, historical flood elevations (including date of occurrence, and estimated frequency), utility elevations, controlling backwater feature elevations (building floor levels, yards, cultivated fields, roadways, drives, other drainage structures, overtopping controls), general classification of stream bed and bank materials (clay, silt, sand, gravel, cobble, rock), plot rock line if identified

(3) The centerline of structure should show: stream bed, top of bank, existing and proposed roadway cross-section, normal water surface profile, historical flood levels, controlling feature elevations properly positioned along the profile, rock line if identified.

(4) Any additional stream cross-sections utilized for design or needed for structural excavation estimates are to be plotted on the survey report. The drawing scale for these sections can be adjusted as needed to fit the report.

Information to be provided on the plan view:

(1) Natural features - stream channel showing base and banks, limits of the floodplain

(2) Type of cover

(3) Manmade features -buildings, houses, highways, existing drainage structures, utilities

(4) The proposed roadway section and fill slope limits

(b) For 72 inch pipe size and smaller, the site data will be summarized on the pipe data sheet. The engineer will also need to reference the drainage plans for topographical and proposed layout information.

(2) Hydrologic Analysis

There are four discharge levels that must be evaluated for each culvert design. These are:

(a) A "design discharge" as listed and defined in the hydrology section (Table 4-3,Chapter VI)

(b) $Q_{100}$ base flood

(c) Q-overtopping. This discharge is computed after a trial size is selected.

(d) $Q_{10}$ for outlet protection and erosion control measures

Other discharges may be required on a site specific basis. Examples are:

(a) Q-average - for permit determination

(b) Q-bank full - for fish passage, channel stability or floodplain analysis.

(3) Hydraulic Design

(a) The first step in hydraulically analyzing a culvert is to address criteria and information that must be quantified prior to commencing actual structural sizing and location. This would include:

Material Selection
A material selection recommendation must be provided for each pipe culvert. The general selection policy is as follows.

Culvert pipe shall be concrete with the following exceptions :

- the expected fill height over the structure exceeds the maximum values for concrete as provided in the N. C. Division of Highways charts,(Appendix H)
- the required invert slope is greater than 10%.
- If a majority of the installations for a project require metal, then all culvert pipe for the project can be metal.

Other site or project specific factors such as, corrosive conditions, accessibility, environmental requirements, handling and initial cost may dictate the use of a particular material.

Box culverts are generally cast in place or precast concrete. There are large metal structures, arches and box shapes, with and without bottom plates, that can be considered for sites requiring large openings and/or spans. The primary source of information on available sizes and structural details is the manufactures literature.

Appendix H provides gage requirements and fill limitations for metal and concrete structures.

End Treatment

Headwalls are generally used on the inlet end of pipe culverts 36 inch or larger. The outlet end does not require a headwall unless site specific conditions such as right-of-way limitation warrant placement of an outlet headwall. For guidance on end treatment of parallel pipes, reference section 5-20, of the Roadway Design Manual (16).

Allowable Headwater

The allowable headwater elevation is established based on an evaluation of natural flooding depths, upstream structures and land use, as well as the proposed roadway elevations.

Multiple Openings (width)

When the width of the structure opening is significantly wider than the natural channel, an evaluation must be made of the affect on flow capacity which will occur when the low flow area is restricted to its natural width by artificial or natural means.

Alignment

As near as is practicable, a culvert should inter-cept an outlet flow within the natural channel. When channel realignment is required, a natural channel design should be utilized (see section X).

Length and Slope

The slope of a culvert should approximate that of the natural channel. The invert elevation should be slightly below the natural bed ranging from 0.1 +/- feet for small pipes to 1.0 +/- feet for large box culvert. Where fish passage is a primary consideration, the invert should be a minimum of 1.0 feet below the natural bed. Baffles may be placed in the invert to promote retention of bed material and formation of a low flow channel. When a shallow (3-5 foot max. depth) non-erosive rock foundation is found throughout the proposed site, the structure can be built on footings without a bottom allowing retention of the natural channel bed. The Geotechnical Unit must confirm the foundation acceptability prior to final selection of the “bottomless” culvert.

Potential channel cleanout and improvements should also be considered particularly in the coastal plain. The length is established by the geometry of the roadway embankment, the bed elevation and skew.

Tailwater

The computed normal channel depth for each discharge level being evaluated generally establishes the tailwater. This can be determined by a simple single section analysis. Effects of downstream controls and constrictions must also be considered.

Debris

The structure opening should be reasonably sized to provide for debris. The limitation of structural height to headwater depths in the HW/D = 1.2+/- range has proven to limit problems of this nature to acceptable levels. Where experience or physical evidence indicates the water course will transport a greater than normal size or volume of debris, special debris controls should be developed and/or the estimated capacity of the structure reduced to reflect the potential for blockage.

(b) A trial size culvert can be determined using the design discharge, inlet control nomographs (HDS-5 ref.- 12)and an assumed HW/D = 1.2. Multiple openings may be selected by dividing the discharge.

(c) When a trial size selection is reasonable in regard to available sizes (see Appendix H ) and allowable headwater limitations, the full inlet/outlet control analysis is performed. The higher of the computed headwaters governs.

(d) If the analyzed size is acceptable in regard to controls and criteria relative to the design discharge, verify it being the minimum acceptable by checking the performance of a smaller structure.

(e) If inlet control governs, improved inlet design must be investigated. This will be performed for all inlet control box culverts and for pipe culverts 36 inch and larger with lengths > 150 ft.

If as much as one nominal size reduction can be achieved for box culverts, the improved inlet option can be selected. For pipe culverts, an economic analysis is required to justify the selected option.

(f) Determine the design values and acceptability of the selected culvert for the $Q_{100}$ and overtopping flood.

(g) Outlet velocities shall be determined for the $Q_{10}$ discharge. If this velocity exceeds the scour velocity for the receiving stream, rip rap outlet protection is required.

(1) See channel chapter for permissible velocity guidelines

(2) Use whichever is greater, tailwater depth or normal flow depth for culvert to determine outlet velocity.

(4) Design Documentation

All information pertinent to the culvert design shall be documented on either the "Culvert Survey and Hydraulic Design Report" or the "Pipe Data Sheet". This will include:

(a) For box culverts, plot the proposed structure in plan and profile views. Note centerline station and skew. Show invert elevations and skew, or top of footing elevations.

(b) Show design water surface elevation on all views.

(c) Complete fill-in of data for selected structure on report or data sheet.

(d) If design is accomplished by computer program, private engineering firms must submit data file summaries on an IBM compatible disk.

(e) For large culverts (>72 inch), a plot of the performance curve for the selected structure with a plot of the natural stage-discharge relations is desirable.

(f) Provide stream classification.

## IX. STORM DRAINAGE SYSTEM

The purpose of a storm drainage system is to collect and transport storm water runoff from the highway to an outlet. The complete system consists of the curb and gutter, inlet structures, lateral and trunk line pipes, and junctions and manholes. The design process for storm drainage systems usually follows the basic steps of planning/data collection, hydrologic/hydraulic design, and outfall analysis. The procedure presented herein will be directed toward non-computer analysis. The pavement and inlet design may be accomplished by a computer program which follows the procedures of HEC 22(6). GEOPAK Drainage is an acceptable automated analysis process for storm drainage system design.

### (1) PLANNING AND DATA COLLECTION

Information gathered during the pre-design study and field surveys that is of particular relevance to the storm drainage system should be assembled for design reference. Planning includes the identification of controls and criteria which must be considered in accomplishing the design. This would include:

#### (a) Design Frequency

Roadway inlet location, capacities and gutter spread is to be analyzed using a standard rainfall intensity of 4.0 inches/hour. The storm drain pipe system is to be designed using a $Q_{10}$ discharge with a minimum time of concentration of 10 minutes assuming 100% pick up at each inlet.

In sag areas where relief by curb overflow is not provided the system standard design level ($Q_{25}$ - $Q_{50}$) is to be used for analysis to insure traffic flow is not interrupted.

#### (b) Gutter Grade

A minimum gutter gradient of 0.20 percent (0.30 desirable) shall be utilized. When lesser slopes are encountered, the gutter shall be warped to provide the minimum slope. A continuous inlet system such as a slotted or trench drain may be used in sag or low gradient gutter sections.

#### (c) Inlets

The standard inlet for curb and gutter is a combi- nation grate and curb opening (std. no. 840.01 of Roadway Standard Drawings-(17). Use of other type inlets for curb sections require project specific approval.

Standard grated drop inlets shall be used in roadway ditches, non-curbed shoulders and other

off

roadway locations. Grates of 2 inch or less(small dimension opening) shall be used in areas subject to pedestrian traffic. Traffic bearing grates are to be used for drop inlets within 4 feet of a permanent or temporary travel lane.

The following specific criteria shall be followed in inlet analysis.

- On grades, the curb opening can be ignored in determining inlet capacity. The grate efficiency shall be assumed to equal a parallel bar grate.

- Inlet capacity at sags shall allow for debris blockage by providing twice the required computed opening.

- Inlet spacing shall be sufficient to limit spread to no more than half of a through lane during a 4.0 inch per hour rain storm.

- When the typical section includes a full shoulder or parking lane, no encroachment into the travel lane will be allowed.

- Depth in gutter shall not exceed 5 inches for design flow.

- While there is no maximum spacing for inlets, no trunk line pipe should extend more than 500 feet without access. An exception is made for median and side ditch systems where 700 feet is an acceptable upper limit.

- Pipe systems shall not decrease in size in the downstream direction.

- Provide 0.5 foot minimum from hydraulic grade line to top of inlet grate or junction.

(d) Pipe System

Storm drain pipes shall be concrete unless a site limitation such as grade or corrosive conditions dictate the use of an alternate material.

The minimum pipe size to serve a single inlet is 12 inches. For more than one inlet, or a length of more than 100 feet, a 15 inch pipe is the minimum size.

When differing size pipes enter and exit a junction the desired practice is to match the crowns of the pipes.

(2) Hydrologic and Hydraulic Design

Storm drainage system design is a two phase process involving first a selection of the required surface inlets, followed by the design of a subsurface pipe system to serve the surface pickups. Automated design systems such as GEOPAK Drainage provide an advanced tool for storm drainage design. However, the following basic design procedure is applicable and can be used for non-automated design, or as a guide to the designer in understanding the analysis process so that he can better interpret the output from an automated design. A similar design procedure is presented in HEC-22(6).

(a) Inlets

(1) Prior to commencing the hydrologic/hydraulic analysis of the surface system a layout of locations requiring inlets should be developed on a set of plans. This would include sag points, upstream of intersections, upgrade of superelevation rollovers, and at locations required to junction back-of-the curb pickups.

(2) With the above noted locations determined, the next step is to analyze the runoff and spread along the roadway to establish additional required inlet locations to meet spread and depth criteria. The hydrologic method used shall generally be the rational formula and will follow the guidance of Chapter VI (Hydrology). The general procedure as outlined in Chapter V (Drainage Plans) shall be used to confirm drainage boundaries, flow paths, outlet conditions and other project special design features.

The design is to be documented on a form similar to Appendix I (Sheet 1 of 7). The inlets should be numbered in a logical ascending order and their location referenced to a project station.

(b) Pipe System

(1) The next step is the layout of a pipe system to provide a connecting route of flow from the inlet(s) to the proper outlet point(s).

(2) Sizing of the individual pipes is now

accomplished. The following procedure involves a run through the system from beginning to end with selection of pipe sizes by utilizing Mannings' flow capacity equation, with the limitations on maximum pipe capacity presented in Appendix I, sheet 6. Sizing of most systems by this procedure is generally sufficient.

While a check of the system by development of a hydraulic grade line requires minimum additional design time when utilizing an automated design process such as GEOPAK Drainage, a manual procedure can be very time consuming. Therefore, the engineer must evaluate and justify the need for a hydraulic grade line check of a system on a case by case basis. Conditions that may warrant undertaking this additional design analysis are:

- System with outlets that are subject to high tailwater conditions.
- Systems that transition from a steep to flat gradient.
- Systems on flat gradient that have substantial junction and/or bend losses.

## Pipe System Design Procedure

Reference Appendix I, sheet 2, for initial system design documentation.

Items 1 - 2. These are inlet numbers corresponding to inlet computation sheet.

Item 3. Total drainage area served by the section of pipe.

Item 4. Sum of the incremental portions of the drainage area and corresponding runoff coefficients.

Item 5. Length of the pipe run between study points.

Item 6. Time of concentration for portion of drainage area in-flowing at beginning end of pipe.

Item 7. Flow time for first pipe equals inlet time. Subsequent sections are a sum of the time of concentration of the previous reach (min. $t_c$ = 10 minutes) plus time of flow in subject pipe.

Item 8. Larger value from Items 6 and 7. Use 10 minutes as minimum value. For times greater than 30 minutes, a flood hydrograph or other routing procedures is recommended.

Item 9. Design storm rainfall intensity for duration equal to design time.

Item 10. Design discharge for pipe reach.

Item 11. Invert elevation of pipe inlet.

Item 12. Invert elevation of pipe outlet.

Item 13. Invert slope of pipe.

Item 14. Diameter of pipe. This size is to be selected utilizing Mannings' full flow capacity equation.

$$Q = 0.46/n\ (D^{2.67})(So^{0.5})$$

A nomograph solution for this equation is provided in Appendix I, sheet 3.

The capacity utilized for design cannot exceed the values contained in the table - Appendix I, sheet 6

Item 15. Velocity based on design discharge and selected pipe size (can use charts Appendix I).

Item 16. Remarks.

## Hydraulic Grade Line Development Procedure

A Hydraulic grade line will provide the potential elevation, under design conditions, to which water will rise in the various inlets and junctions. This can serve as a check for potential unacceptable outflow or pressure problem areas within the system dictating a change in the system design.

Reference, Appendix I, sheet 7, for tabulation of the procedure.

Item 1. The inlet number or junction location immediately upstream of the outlet.

Item 2. Water surface elevation at outlet or 0.8D + invert elevation of the outflow pipe, whichever is greater.

Item 3. Diameter ($D_o$) of outflow pipe.

Item 4. Design discharge (Qo) for the outflow pipe.

Item 5. The length ($L_o$) of the outflow pipe.

Item 6. Friction loss ($H_f$) for full pipe flow. Loss due to flow in the pipe can be computed by multiplying pipe length ($L_o$) x friction slope ($S_f$). Friction slope can be determined from pipe flow charts or by using the formula:

$$S_f = [Q/K]^2$$

$$K = 1.0/n\ (AR^{0.67})$$

Appendix I, sheet 5 provides values of (K) for various pipe sizes.

Item 7. Contraction loss (Hc). Loss due to contraction of flow at inlet of outflow pipe. Computed by the formula:

$$H_c = 0.25\ (V_o^2/2g)$$

Where: $V_o$ = Flow velocity in outlet pipe (full flow)

Item 8. Expansion loss ($H_e$). Loss due to expansion of flow into the junction. Use expansion loss from primary inflow line.

$$H_e = 0.35\ (Vi^2/2g)$$

Where: $V_i$ = Flow velocity in inlet pipe (full flow)

Item 9. Bend loss ($H_b$) loss due to change in direction of flow. Use change in angle of primary flow line.

$$H_b = K\ (Vi^2/2g)$$

| | |
|---|---|
| 90 degrees K = 0.70 | 40 degrees K = 0.38 |
| 80 degrees K = 0.66 | 30 degrees K = 0.28 |
| 70 degrees K = 0.61 | 25 degrees K = 0.22 |
| 60 degrees K = 0.55 | 20 degrees K = 0.16 |
| 50 degrees K = 0.47 | 15 degrees K = 0.10 |

Item 10. Total losses (Ht), sum of friction, contraction, expansion, and bend losses.

Item 11. Inlet water surface elevation. This is the potential water surface elevation within the inlet or junction.

Item 12. Inlet rim elevation or top of junction. The water surface elevation is to be a minimum of 0.5 feet below this elevation. If not, the pipe size should be increased or other measures taken to reduce the water level.

Item 13. Remarks.

Repeat the procedure for the upstream junction and plot the potential water surface elevation if above the crown elevation of the outlet pipe.

(3) OUTFALL ANALYSIS

The storm drainage system design must include an evaluation of the downstream receiving channel or system to determine its adequacy. This evaluation should address:

- Potential effects on the receiving stream when identified as an environmentally sensitive stream. (reference chapter XII)
- Potential effects on the highway facility due to downstream inadequacies.
- Potential effects to other properties due to the inadequacies.
- Affect of the highway improvements on the downstream facility. (Percent increase in quantity, velocity, depth, etc.)
- Potential corrective measures. (Including cost).
- Recommended actions.

## X. CHANNELS AND ROADSIDE DITCHES

A channel is any open conveyance, natural or man-made, in which water flows with a free surface. A roadside ditch is a man-made channel generally paralleling the roadway surface and distinguished by a regular geometric shape. The design process and analysis requirements for roadside ditches and channels differ. For the purpose of this chapter, "channel" shall refer to all open conveyance facilities not classified as roadside ditches or requiring more than a 2.0 foot base. The design procedure presented is general and intended to present specific criteria and analysis requirements. The Engineer should reference FHWA, HEC-11, (18), HEC-15 (19), and Chapter VI of the AASHTO Drainage Guidelines(1)for more detailed design guidance.

### Roadside Ditches

The following is a basic step procedure for evaluating and/or designing roadside ditches.

(1) Establish a ditch plan which shows the proposed ditch locations and flow patterns.

This ditch plan is a part of the drainage plan (Chapter V, Item 7).

(2) Determine the standard or typical ditch cross sections for the project.

This is provided by the roadway plans typical sections. When a ditch is required along the construction limits which is not part of the typical section, the following Criteria are to be followed in establishing a typical section.

- A standard berm ditch section shall be noted at top of cut where required.
- Toe of fill ditches adjacent to shallow fills and flat slopes (4:1 or flatter) shall be formed by continuation of the fill slope to a desired ditch depth, provision of a base width if required, then a stable back slope (2:1 maximum).
- Toe of fill ditches adjacent to high steep slopes shall be constructed with a minimum 2.0 foot berm. A wider berm is desirable for very high fills to prevent

embankment from filling the ditch and for maintenance if access is limited from the off roadway side.

(3) Determine the gradient to be used on all proposed ditches.

Roadway ditches included in the typical roadway section will have a grade corresponding to the roadway profile. When the roadway profile grade is less than 0.3%, special roadway ditch grades may be established and noted on the plans.
Ditches along the toe of fill will generally parallel the grade of the natural ground at an established acceptable depth. The approximate grade of these ditches are to be established and plotted on the plan profile view.

(4) Investigate capacity of the established typical ditch.

Roadway ditches are to be designed to contain as a minimum the Q5 flow The typical roadway ditch section is established with sufficient depth to drain the pavement subbase and flat side slopes for safe vehicle traversability. This generally provides very generous capacity for the design flow requirements. Therefore, actual capacity determination can be done on a selective basis at sites on common project grades to verify adequacy and establish limitations on the length of ditch run.

The size requirements of the project special side ditches along the toes-of-fill will be established based on an analysis of the design flood. This ditch capacity analysis will be performed using Mannings' equation:

$$Q = (1.49\ AR^{2/3}\ S^{1/2})/n$$

Discharge determination shall follow the requirements of Chapter VI - Hydrology. The roadway section including shoulders and slopes shall be considered an urban watershed. This capacity analysis is usually worked in conjunction with the next step of lining evaluation.

(5) Determine the limitations and protection requirements to prevent erosion in the ditch.

The stability of vegetative ditch linings is to be analyzed by use of Charts 1 and 2 (Appendix J). These charts are based on the more frequently used 'V' and base ditch sections. However, a procedure and example are included for evaluating other channel configurations. The stability limitation is based on an established acceptable velocity. When applying the chart, if conditions at a particular site are such that you fall to the left of the stability line, a good vegetative cover would not be expected to erode. Conversely, if you are to the right of the line, the ditch would be expected to be unstable and erode when subjected to design flow even if a good vegetative lining were established; therefore, some type of armoring (rip rap, concrete paving) must be used.

Charts 3 and 4 (Appendix J) are provided to analyze the stability of rip rap ditch linings (Type A, B, and Class I rip rap). They are used in the same manner as Charts 1 and 2 to determine the stability of stone lining under differing ditch shape and flow conditions.

(6) Determine any special measures necessary at or downstream of the ditch outlet.

A check should be made of the transition of flow from a ditch to the receiving outlet. Factors to be considered are:

(a) Is there provision for a smooth transition of flow from the ditch to the outlet?

(b) Will the outlet adequately handle the quantity of flow? Is improvement required?

(c) Is the velocity of flow at the outlet too high for the condition of the receiving channel? Is riprap or other means of velocity reduction justified?

(d) When the receiving outlet is sheet overland flow, is concentration of flow by the ditch a potential problem? Is some form of flow diffusion required?

Channels

Channel analysis differs from roadway ditch analysis in that it involves establishing a channel configuration to meet specific site hydrologic, and geomorphic requirements. The requirements for analysis can range from simple sizing of small ditches constructed adjacent to the roadway fill to intercept and convey discharge to points of acceptable outlet, to complex studies of extensive natural stream and river relocation. In addition to the guidance provided in this document the engineer is directed to FHWA, Hydraulic Engineering circular #15 (16) and Chapter 8 of the AASHTO Model Drainage Manual (2),for further guidance for small ditch and channel analysis. For larger stream involvement, FHWA “Highways in the River Environment”(20), “Applied River Morphology”(21), by Dave Rosgen and the NC Wildlife Resources Commission, “Guidelines for Stream Relocation and Restoration in North Carolina”(22), are suggested references.

Channels that are realignments of natural streams should be sized and configured to match as near as practicable the natural channel system. For small, "minor relocation" of streams at the inlet and outlet of structures (less than 100 feet total, <50 each side). The engineer is directed to "Stream Relocation Guidelines" developed jointly by representatives of the NCDOT and the NC Wildlife Resources Commission in 1993 (Appendix M).

If relocation of a stream channel is unavoidable, the design of the replacement channel should provide dimension, pattern and profile that affords natural stability. A proven and accepted method of study for natural channel involvement is through a process of stream classification. The overall objective of classifying a reach of streams is to set categories of types based on morphologic characteristics, so that consistent, reproducible descriptions and assessments of conditions and potential can be developed.

Some specific objectives of a classification system are: ( From “Applied River Morphology “,Dave Rosgen)

- Provide methodology for predicting a streams behavior from its appearance (classification).
- Guide development of specific hydraulic and sediment transport relationships for stream type and state.
- Provide mechanism for comparison of data for stream reaches having similar characteristics.
- Provide a consistent frame of reference for communicating stream conditions and morphology across disciplines.

The recommended sequence of a channel analysis should be as follows (more detailed guidance is provided in the recommended references).

1) Data Collection

Data collection includes office study as well as a field survey. Much of the information needed for initial classification can be obtained from topographic mapping and aerial photography. The field survey provides more detailed information for refinement of the initial classification as well as the analysis and design process. It should include as a minimum the collection of the following data:

Needed for Classification

- channel width (bankfull)
- channel depth (section mean)
- maximum depth (at bankfull)
- bankfull cross section area

- slope (average for at least 20-30 channel width reach)
- stream length (20-30 bankfull channel widths in length)
- valley length (20-30 bankfull channel widths in length)
- bed material (type, size [$D_{50}$])
- bank material (type, size [$D_{50}$])
- width of flood-prone area

Needed for analysis and design:

Channel Dimension
- pool depth
- pool width
- pool area
- riffle depth
- riffle area
- maximum pool depth

Channel Pattern
- meander length
- amplitude
- radius of curvature
- belt width

Channel Profile
- valley slope
- riffle slope
- average water surface slope
- pool slope
- pool to pool spacing
- pool length

2) Stream Classification

With the data collected and further determination of stream features such as;

- entrenchment ratio,
- width/depth ratio, and
- sinuosity,

a stream type classification can be established. (See Reference (18), "Applied River Morphology".)

3) Existing Conditions

It is important to assess the condition of the stream as it relates to stability, state and causes of changes, potential future impacts and hydrologic and hydraulic requirements. This assessment process should address:

- the watershed,
- flow regime,
- riparian vegetation,
- bank stability,
- bed stability,
- meander patterns,
- sediment supply and transport,
- debris,
- aggradation/degradation,
- aquatic and terrestrial habitat,
- discharge levels and conveyance requirements
- evolutionary trend.

Stream condition gathers through the assessment process apply to a reach of the stream and may vary considerably up and down stream as the character of the valley changes. Some sections may be at such an altered state that existing data and conditions are of little value in developing recommendations for a relocated or restored channel. This is when a reference stream of similar classification and morphological characteristics can be used as a guide for developing study proposals.

4) Proposed Plan

The evaluation process should provide the engineer with information and knowledge necessary to develop a recommended channel relocation or restoration proposal that meets hydrological and ecological requirements and provides a natural stable system. Wildlife resource specialist should be consulted for input during the design process.

5) Design Documentation

All information pertinent to the channel design shall be documented in an appropriate design report format.

## XI. EROSION AND SEDIMENT CONTROL

A plan for controlling erosion and sediment during construction will be prepared by the Roadside Environmental Unit and incorporated into the final project plans. The engineer developing the drainage plans will be responsible for the following items relating to sediment and erosion control:

A-BASINS

These are large sediment trapping facilities composed of a dam, storage/trapping area and an outlet spillway structure. They are generally limited in use to disturbed areas of 5 acres or more and require thorough analysis and design to insure;

- adequate storage volume for expected sediment
- adequate retention to allow settlement
- a dam and spillway capable of handling expected flow

The hydraulics engineer will include design details and recommendations for A-Basins at sites identified as potential locations during the initial design process. These will be included in the preliminary right-of-way plans and available for review during the preliminary field inspection. If the recommended basins are not felt to be required by Roadside Environmental or construction personnel responsible for erosion and sediment control during construction of the project, they are to be deleted from the plans. If additional or alternate sites are identified and requested by others for addition to the plans, detailing and right-of-way requirements will be developed for inclusion in the plans.

Detailing of the basins must be site specific to fit the local topography. Appendix K provides special detail sheets for documentation of the basin design. The following criteria will provide some minimum limits, special details and general guidance in the basin design.

Storage/Trapping Area

- Minimum storage below top of riser:
  2700 cubic feet per disturbed acre

- Minimum surface area:
  $Q_2$ X 350 $ft^2$

- Plan dimension:
  minimum length = 2 X width at dam

- Excavation:
  If the design requires excavation to attain minimum storage, slopes are to be 2:1

Spillway (Riser)

- Minimum riser diameter: 15 inches
- Minimum riser height above barrel invert: 2 X riser diameter, not to exceed 9.0 feet
- Diameter of riser is equal to barrel
- Riser hydraulic requirement: The riser must convey the $Q_2$ discharge with a head no greater than 0.5 times the diameter or 1.0 foot, whichever is less. A weir coefficient of 3.0 is to be used for the analysis of diameters of 15-36 inch, 3.5 for 36 inch and greater.

Spillway (Anti-flotation)

- Minimum depth of riser below barrel invert: 1.0 foot
- Weight of filter stone and trash rack are not considered in computing ballast force.
- Weight of the riser, steel base plate (if used) a portion of the barrel ( 2X diameter) and ballast (concrete or stone) are considered in computing ballast force.
- Weights to be used in computation;

| | | |
|---|---|---|
| Concrete | = | 86#/cubic foot |
| Stone | = | 62#/cubic foot |
| Steel Plate | = | 9#/square foot(0.25 in. thick) |
| CS Pipe | = | 15″- 10 #/LF |
| | | 18″- 13 #/LF |
| | | 24″- 17 #/LF |
| | | 30″- 26 #/LF |
| | | 36″- 31 #/LF |
| | | 42″- 51 #/LF |
| | | 48″- 58 #/LF |
| | | 54″- 65 #/LF |
| | | 60″- 90 #/LF |

- Volume of the entire riser above the invert and a portion of the barrel equal to twice the diameter are to be used to compute the buoyancy force.
- A minimum safety factor of 1.2 is required.

Spillway(Overflow)

- Must be founded entirely in natural ground including side slopes
- Elevation must be 1.0 feet above top of riser
- Must be adequate in size to convey the entire $Q_{50}$ discharge with a maximum weir head of 1.5 feet. A weir coefficient of 3.0 is to be used for spillway performance analyses.

Embankment

- Slopes 2:1 or flatter
- Minimum top width: 6 feet for 15”-36”
  8 feet for >36”
- Minimum top elev. = $Q_{50}$ WS + 0.5
- Maximum Height:
  Not to exceed 12 feet above lowest toe or barrel invert

CONSTRUCTION PHASING FOR BOX CULVERTS

This is a recommended step by step plan for the construction of a structure including requirements for; temporary handling of flow, required temporary erosion control items, and structure staging. This is an identified acceptable method. There may be others that are more appropriate and acceptable. This should be discussed and an agreed to plan developed during the field inspection.

The final phasing plan must include:

- A means of handling flow through the site (ex. diversion pipes or channels)
- A sequence of construction and appropriate sediment controls
- Placement and sizing of a stilling basin for storage of pumped effluent for de-watering
- Detailing of any temporary easements required

PERMANENT CONTROLS

Permanent control measures such as ditch lining and pipe outlet protection are included in the drainage plan recommendations and report.

# XII. STORMWATER MANAGEMENT

Generally, stormwater pollution can be categorized as Point Source (PS) and Non-Point Source (NPS) pollutants. PS pollutants are defined as any source of pollution that enters the surface water of the U.S. through pipes, ditches, channels, etc. Typical examples of PS pollution include industrial and municipal wastewater discharges. NPS pollution is pollutant that comes from overland runoff from agriculture and urban areas. A typical examples of the NPS pollution is fertilizer nutrients that washed off farmlands, golf courses and lawns.

Due to its various types of activities, the N. C. Department of Transportation generates both PS and NPS pollutants. Examples of sources of PS pollutants are maintenance yards, equipment shops, storage facilities (such as salt, fuel, herbicide, fertilizer, etc.), ferry operations and highway stormwater drainage systems.

An Example of NPS pollutant is stormwater runoff from highways with only vegetative shoulders, embankments, and ditches. The pollutants can be generated from various highway activities, which include clearing and grubbing on construction sites, accidental spills, application of, deicing agents, fertilizers, herbicides, and paints. The major constituents of stormwater runoff pollutant from highway runoff are; oil, grease, nitrates, phosphorus, chromium, cadmium, lead, zinc, iron, manganese, copper, chlorides, sulfates and particulates.

The goal of this chapter is to provide a method for evaluation of potential impact of proposed actions, and a procedure for development and implementation of stormwater management practices to protect the quality of the receiving surface waters in the planning, design, construction, and maintenance of a multi-functional transportation system.

## Stormwater Regulations and Programs

### Federal Laws

In 1977 the U. S. Congress amended the Federal Pollution Control Act to regulate the discharge of pollution into waters of the U.S. and it was officially designated the Clean Water Act (CWA). It serves as the cornerstone of Federal law for all water quality programs. It directs the Environmental Protection Agency (EPA) and other regulatory agencies to establish standards of water quality for states to follow.

In 1987 Congress passed a further amendment to the act which added stormwater permits to the NPDES program under Section 402. Section 404 of the Act defines navigable waters of the United states and requires permit authorization for the discharge of dredge or fill materials into these waters. A new section ( Section 319) addresses nonpoint source pollution. Section 319 requires each state to better integrate the Coastal Nonpoint Program and the Statewide Nonpoint Program. Pursuant to Section 401 of the Act, issuance of permits under any of the above Sections of the CWA is contingent on receipt of water quality certification by the State in which the discharge originates.

### State Laws and Programs

A State Sedimentation Pollution Control Act was adopted in 1973. This promulgated rules and regulations to control accelerated erosion and sediment resulting from land disturbing activities. The Department of Transportation has been delegated the authority to administer an erosion and sediment program within the department. Guidance for the Hydraulics Engineers' responsibilities in this activity is provided in Chapter XI of these guidelines.

In 1988 the EMC adopted Coastal Stormwater Rules to regulate development activities in the states 20 coastal counties. The rules require developers obtaining CAMA permits to include stringent sediment and erosion control and stormwater management plans. The rules provide low-density and high-density development options. The low-density option allows construction area up to 25% of the lot for sites within one-half (1/2) mile and draining to Class SA (Shellfish) waters and 30% for other coastal areas. The high-density option requires on-site stormwater control measures, such as retention and detention basins.

Highway projects were considered to be exempt from obtaining individual action approval under subparagraph (a)(6), “ otherwise meets the provisions of the rule and has boat ramps, public roads and bridges which minimize impervious surfaces, diverts stormwater away from surface waters as much as possible and employs best management practices to minimize water quality impacts”.

This act was amended and enacted on Dec. 1 , 1995 expanding requirements to include development activities; draining to Outstanding Resource Waters, and those within one mile of and draining to High Quality Waters. A general permit for NCDOT roadway development activities was issued concurrent with the NPDES stormwater permit.

In 1989 the Water Supply Protection Act to protect drinking water supplies was passed by the State Legislature. It directed the Environmental Management Commission (EMC) to adopt regulations and implement the programs. It also classified the waters of the state based on their quality and significance to the municipalities.

Highway projects were addressed under Section (m) of the final adopted rules on February 13 ,1992. “The construction of new roads and bridges and non-residential development should minimize built-upon areas, divert stormwater away from surface water supply as much as possible, and employ best management practices (BMPs) to minimize water quality impacts. To the extent practicable, the construction of new roads in the critical area should be avoided. The Department of Transportation shall use BMPs as outlined in their document entitled ,” Best Management Practices for the Protection of Surface Waters”(23).

An NPDES permit for the NCDOT was issued on June 8, 1998. Requirements contained in the permit address a broad range of DOT activities. Included is a requirement for development of a procedure to document newly constructed stormwater outfalls and add them to a stormwater system inventory of existing facilities. This documentation process will include the development of project stormwater management plans described later in this chapter.

On December 11, 1997, the Environmental Management Commission (EMC) approved the Neuse River Nutrient Sensitive Waters (NSW) Management Strategy. This strategy establishes a goal to reduce annual nitrogen delivery to the Neuse River Estuary from point and nonpoint sources by a minimum of thirty percent (30%). Mandates have been proposed for point source discharge, urban stormwater management, animal operations, riparian buffers, and nutrient management.  A temporary riparian rule became effective in January 1998, the entire package of rules is to go into effect August 1, 1999.

The riparian rule requires the protection and maintenance of existing forested buffers on each side (50 feet) of surface waters in the Neuse River Basin (intermittent streams, perennial streams, lakes, ponds, and estuaries) as indicated on the most recent version of United States Geological Survey (1:24,000) topographical maps. Certain permitted uses and exemptions that affect highway activities are:

- Ditches- existing ditches through the riparian area may be maintained. New ditches can not be cut through the riparian area and flows must be dispersed into sheet flow before entering the buffer.
- Road crossings- Road crossings through the riparian area are allowed, provided they show that no practical alternative exists. They are designed, constructed and maintained to minimize disturbance and protect water quality. Application for this exemption must be made to DWQ Wetland/401 Unit.

Impact on DOT project development activity from the remaining sections of the final rule are anticipated to be limited to urban stormwater management. Required project measures are expected to be the same as those contained in the stormwater rules for coastal, high quality and outstanding resource waters.

## Best Management Practices (BMPs)

In March 1997 NCDOT published a handbook entitled "Best Management Practices for Protection of Surface Waters"(20). BMPs are defined as activities, practices and procedures undertaken to prevent or reduce water pollution. They are categorized as preventive and control measures .Preventive measures, also referred to as Non-Structural BMPs, are conceptual management or design practices which eliminate or reduce pollutants at the sources. Control measures, also called Structural BMPs, are engineered means to remove or reduce the concentration of pollutants from the runoff before they enter the receiving streams. The BMP document serves as a compendium covering both preventive and control measures that are implemented in NCDOT's various activities. These activities include general maintenance operations and facilities, construction operations including temporary erosion and sediment control, as well as project planning and design.

Many non-structural BMPs should be considered in the project planning process and initial establishment of general criteria for design to lessen potential for pollutant impact on the receiving streams. Some examples are listed below. Further reference should be made to NCDOT, “Best Management Practices For Protection of Surface Waters”(20).

- Chose alternatives such as widening the existing roadways over new location.
- Use design alternative such as grass medians and shoulders in lieu of impervious materials.
- Select roadways options with shoulder sections over curb and gutter sections.

More site specific BMP usage, including structural BMPs is discussed in the stormwater plan preparation section.

## Stormwater Management Plans

The Hydraulics design engineer must develop a Stormwater Management Plan (SMP) as well as drainage recommendations. The SMP will be in a report type format, which reflects the following sequence of development.

- Identify Project Involvement
- Evaluate Potential Impact
- Select and Implement BMPs
- Prepare Design Details

### Identify Project Involvement

The design engineer should first review the project planning document for environmental concerns and commitments. The engineer should also investigate the classifications of all stream crossings using the environmental sensitivity base maps, which were jointly developed by the NCDOT, NCDENR and other governmental agencies. These maps are 1:100,0000 scale and are updated every five years. They depict all regulated waters in North Carolina. These include water supply, coastal, outstanding resource, and high quality waters. Other water classifications which warrant particular consideration are Trout and Nutrient sensitive.

Resulting from this step should be a listing of stream crossing and/or discharge sites that require evaluation for potential impact. A finding that there are no sites requiring special consideration is a potential outcome.

Evaluate Potential Impact

The Hydraulics Engineer will perform a preliminary evaluation of the potential impact of the proposed project on the receiving stream at each individual site. The evaluation at this point will be somewhat subjective, but will be based on sound judgment and experience. The following parameters should be considered in the evaluation process.

- The proximity of the discharge point to the receiving stream. Is this a direct discharge or is there sufficient area for dilution?
- The volume and type of traffic. Is the volume in excess of 30,000 ADT? Is there heavy truck and/or high potential pollutant traffic?
- The ratio of the impervious surface of contributing highway area to the total watershed of the receiving stream.
- Preventive BMPs that are employed.
- Value of the water resource.
- Site highway geometry and potential for accidental spill.

If this preliminary evaluation suggests that the proposed roadway poses a low risk to the receiving streams, the hydraulic design engineer may document the assessment and conclude that standard BMPs are sufficient for protection of the receiving waters and that no special control measures will be required.

If the preliminary evaluation suggests that the proposed roadway may pose a risk to the receiving streams, the hydraulic design engineer should proceed as follows:

1. Define the target pollutants to be evaluated at the site of interest.

2. Determine the loading of the major pollutants from the proposed highway, based on; traffic counts and types, roadway types, drainage

areas, etc. Reference Chapter 3 of FHWA, "Evaluation and Management of Highway Runoff Water Quality,"(17).

## Select and Implement BMPs

In order to effectively reduce the pollutants from highway runoff, the design engineer should investigate both non-structural and structural BMPs applicable to each point source of interest. The investigation should proceed as follows:

1. Evaluate potential BMP control measures for the site, based on the land, topography, soil and roadway types.
2. Investigate the pollutant removal capabilities of these BMP control measures. For design details reference Chapters 3 and 5 of FHWA, "Evaluation and Management of Highway Runoff Water Quality"(24).
3. Conduct cost and risk assessment for each BMP control measure. Cost analysis shall include land, structure, construction and maintenance.
4. Select the most feasible BMP control measure for the site.

For the design details of these control measures, the design engineer may reference the following publications:

1. "Evaluation and Management of Highway Runoff Water Quality, FHWA-PD- 96-032, 1996(21).
2. "Stormwater Best Management Practices", Division of Water Quality of NCDENR, 1995(25).
3. AASHTO Drainage Guidelines, Volume 12,"Stormwater Management",(1).

## Prepare Design Details

To complete the drainage and stormwater design, the design engineer should summarize all the recommended control measures in a "report" type format. The report should first include the overview of the project and scope of the stormwater management plans. It should then identify the names, locations, and classifications of the receiving streams at the outlet of each system. At each outlet, all BMP preventive and control measures should be listed and described in details. Design details should be provided on separate sheets for large structures, such as: detention and retention basins, infiltration basins, and constructed wetlands.

The report should also include major drainage structures, such as bridges, culverts, etc., which are located within environmentally sensitive areas. Any direct discharge from these structures such as deck and approach drains, or direct connection of storm drain systems to the culvert, etc. should be avoided and documented.

## Water Quality Related Practices and Guidelines

### Stream Crossings

As highways cross unique streams, such as trout and anadromous fish streams, special design considerations are required in selecting drainage structures and roadway facilities. It is the goal of the hydraulic design engineers to develop engineering plans which provide favorable aquatic habitats and also are hydraulically feasible and cost effective. In development of the crossing design consideration must be given to the following general guidelines:

1. Flow conditions at normal and bank-full discharges should be thoroughly investigated to ensure that the structures will not impede fish passage.
2. The slope of the replacement culverts should be compatible to that of the existing channel.
3. The bottom slab of culverts should be buried 1 foot below the bed and covered with natural bed materials.
4. Baffles can be installed inside the culvert to promote the establishment of a natural substrate.
5. It is desirable to maintain a normal velocity in the culvert comparable to that of the existing channel
6. In cobble bed stream material comparable to the natural bed material should be placed in the structure.
7. Channel modifications at the inlet and outlet of culverts should follow guidelines presented in the following section.

## Stream Relocation

As the result of highway improvement activities, such as construction of new roads and widening of existing roads, natural streams sometimes are unavoidably filled or encroached upon by the proposed embankment. Unless the natural streams are properly realigned, it may result in an adverse impact on the fish habitats, bank erosion, channel degradation, and flooding problems. The hydraulic design engineers should thoroughly review the physical and dynamic characteristics of the natural streams and develop replacement channels that are ecological, geomorphic and hydraulically compatible. Reference channel section of Chapter X.

## Anadromous Fish

Anadromous fish are a unique and valuable resource. Streams utilized by anadromous fish have been identified on Environmental Sensitivity Maps. While most of the anadromous fish are found east of I-95, they migrate in the Neuse and Cape Fear Rivers as far as Wake and Harnett counties. When a proposed highway crosses anadromous fish streams, the hydraulic design engineer should develop the most practical drainage plans, which will least adversely impact their movement and habitats .Design guidance is present in the department's "Stream crossing Guidelines for Anadromous Fish Passage" (Appendix N).

## Hazardous Spill Basins

Hazardous Spill Basins are provided in new highway construction major improvement projects at strategic locations along arterial system highways to aid in containment and clean up of accidental spills. The determination of these strategic locations is based on concentrated truck usage areas such as parking sites at rest areas, weight stations, and runaway ramps, as well as for highway segments in close proximity to particularly sensitive waters such as outstanding resource waters and water supply sources. For guidance in the design and selection of location for these devices the engineer should reference the department's, "Guidelines For The Location And Design Of Hazardous Spill Basins"(Appendix O).

## XIII. PERMITS

The drainage study and hydraulic design process includes the development of permit drawings and completion of pertinent application forms for State and Federal environmental permits. The material is developed through coordination with the Natural Systems Unit and upon completion is provided to them for submittal to permitting agencies. The procedure for development of the drawings and application should be as follows:

(1) Review the environmental document to obtain wetland area, identifications, jurisdictional streams and other information regarding permit requirements. While the planning documents include delineation of wetland limits, it is not generally of sufficient detail in actual limit description to fully define the project/wetland involvement. This requires detailed field confirmation by the hydraulics designer. If questions arise, the environmental permitting section, must be consulted for assistance in the analysis.

(2) Assemble information gathered during the pre-design study, field survey and design that is pertinent to the permit application. This would include:

- Location and classification of wetland and streams
- Topo. and elevation data at sites
- Drainage structure and/or channel design data
- Watershed area
- Flow data (ex. average, low, bankfull )

(3) Prepare the permit drawings. An example drawing is included as Appendix L. The drawings are to conform to, and should include as a minimum the following:

- Drawings are to be on standard letter-size paper with a 1 in. left margin and ½ in. remaining margins.
- Number of sheets is optional but must be to scale and clearly depict the wetland involvement.
- Location-vicinity maps showing project location and permit site(s).
- Plan view of site(s) including pertinent drainage and roadway features, wetland limits, area of wetland disturbance, fill below ordinary high water, property owners.
- Profile view of site(s) showing roadway grade, natural

ground, ordinary high water, drainage structure, fill below ordinary high water, wetland limits.

- Section view if needed to clarify proposal.
- Quantities for each site of total fill within the wetland area, fill below ordinary high water and acreage of wetland fill are to be included on the sketches.

(4) Complete application form.

With use of electronic drafting techniques which provide many layers of data, it is important that the permit drawings be easy to interpret. To accomplish this, limit the amount of data on the drawings to that which is necessary for clearly identifying the permitted activity and avoid cluttering the sheet with unnecessary information.

# XIV. REFERENCES


(1) AASHTO, *Highway Drainage Guidelines.*

(2) AASHTO, *Model Drainage Manual.*

(3) NCDOT, *Subdivision Roads Minimum Construction Standards*

(4) USGS, WRI-Report 99-4114, *Estimating the Magnitude and Frequency Of Floods in Rural Basins of North Carolina.*

(5) USGS, WRI-Report 96-4084, *Estimation of Flood-Frequency Characteristics of Small Urban Streams*

(6) USGS, WRI-Report 96-4085, *Estimating Flood Hydrographs for Urban Basins in North Carolina.*

(7) FHWA, HEC-22, *Urban Drainage Design Manual.*

(8) FHWA, HDS-2, *Highway Hydrology.*

(9) FHWA, Federal-Aid Policy Guide, 23 CFR 650A, *Location and Hydraulic Design of Encroachments on Flood Plains.*

(10) FHWA, TS-84-204, *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains.*

(11) FHWA, HEC-21, *Design of Bridge Deck Drains.*

(12) FHWA, HEC-18, *Evaluating Scour at Bridges.*

(13) DOTs, Pooled Fund Study, *Tidal Hydraulic Modeling for Bridges- Users Manual.*

(14) FHWA, HEC-20, *Stream Stability at Highway Structures.*

(15) FHWA, HDS-5, *Hydraulic Design of Highway Culverts.*

(16) NCDOT, *Roadway Design Manual.*

(17) NCDOT, *Roadway Standard Drawings.*

(18) FHWA, HEC-11, *Design of Riprap Revetment.*

(19) FHWA, HEC-15, *Design of Roadside Channels with Flexible Lining.*

(20) FHWA, Training and Design Manual, *Highways and the River Environment.*

(21) Rosgen, *Applied River Morphology.*

(22) NCWRC, *Guidelines for Stream Relocation and Restoration in North Carolina.*

(23) NCDOT, *Best Management Practices for Protection of Surface Waters.*

(24) FHWA, PD-96-032, *Evaluation and Management of Highway Runoff Water Quality.*

(25) NCDENR, *Stormwater Management Guidance Manual.*

# Appendices

# HYDRAULIC DESIGN DOCUMENTATION SUMMARY

I.D. # ____________ COUNTY: __________________ PROJECT NO: _________________

DESCRIPTION :

PROJECT ENGINEER: __________________ DESIGN ENGINEER: _________________ DATE:_________

THE FOLLOWING CHECKED DESIGN ITEMS HAVE BEEN DEVELOPED AND ARE CONTAINED IN THE PROJECT DOCUMENTATION FILES:

1. _________ PRELIMINARY DESIGN AND ASSESSMENT OF STREAM CROSSING AND ENCROACHMENTS
2. _________ CHECKLIST FOR DRAINAGE STUDY AND HYDRAULIC DESIGN
3. _________ STRUCTURE SURVEY RECOMMENDATIONS
4. _________ PIPE MATERIAL RECOMMENDATIONS
5. _________ PIPE DATA SHEETS (NUMBER ______ )
6. _________ STORM DRAINAGE COMPUTATION SHEETS (NUMBER _____ )
7. _________ CULVERT SURVEY REPORT(S) (NUMBER _______ )
8. _________ A-BASINS AND CONSTRUCTION PHASING FOR BOX CULVERTS (NUMBER _____)
9. _________ CULVERT SURVEY FIELD NOTES (NUMBER OF SETS _______ )
10. _________ BRIDGE SURVEY REPORT(S) (NUMBER _______ )
11. _________ BRIDGE SURVEY FIELD NOTES (NUMBER OF SETS _______ )
12. _________ PERMIT ACTION LETTER _________________________
13. _________ PERMIT APPLICATION (DATE SUBMITTED _______ )
14. _________ FLOODWAY MODIFICATION (DATE SUBMITTED _______ )
15. _________ OTHER:

# CHECKLIST FOR DRAINAGE STUDY AND HYDRAULIC DESIGN

I.D.: ________ COUNTY: ________________ PROJECT ENGINEER: _______________ DATE: ________

*PRIOR TO FIELD SURVEY (TO BE COMPLETED PRIOR TO FIELD TRIP)*

APPROVED BY ______________________ DATE : ____________

1. HAS PLANNING REPORT BEEN REVIEWED? ARE THERE ANY COMMITMENTS OR REQUIREMENTS WHICH WOULD AFFECT THE DESIGN?

2. ARE THERE ANY PRIOR SURVEYS AT STREAM CROSSINGS? ARE THERE ANY PRIOR SURVEYS AT UP AND DOWNSTREAM STRUCTURES

3 .WHAT IS FLOOD ZONE STATUS?

4.CHECK FOR SCS WATERSHED INVOLVEMENT.

5. ARE THERE ANY STREAM GAGES IN AREA? (DATES AND FREQUENCIES OF MAJOR FLOODS)

6. OBTAIN DRAINAGE AREA AND DESCRIPTION OF EXISTING STRUCTURES.

7. DEVELOP PRELIMINARY DESIGN DISCHARGES AND ESTIMATES OF STRUCTURE TYPES AND SIZES.

8. DETERMINE POSSIBLE PERMIT REQUIREMENTS,

9. PREPARE SKETCHES FROM AVAILABLE FIELD DATA.

10. ARE THERE ANY HYDROLOGIC / HYDRAULIC STUDIES WITHIN THE PROJECT AREA BY AGENCIES SUCH AS: THE CORPS OF ENGINEERS, TVA, CITIES OR COUNTIES?

11. WHAT ARE SOURCES FOR WATERSHED AREA OR DELINEATION?

12. HAS PROJECT INITIATION SHEET BEEN SUBMITTED?

## FIELD STUDY

THE FOLLOWING INFORMATION IS TO BE INCLUDED IN THE FIELD SURVEY NOTES: (CHECK LOCATION AND SURVEY NOTES AND SUPPLEMENT WITH ANY ADDITIONAL INFORMATION THAT MAY BE REQUIRED) ANSWER YES, NO, OR N/A

1. TOPO IS TO INCLUDE BUT NOT LIMITED TO:

a. ________ CHANNEL BANKS AND WATERS EDGES

b. ________ EXISTING STRUCTURES (BRIDGES, CULVERTS, AND STORM DRAINAGE SYSTEMS)

c. ________ UTILITIES (POWER, WATER, GAS, TELEPHONE, SANITARY SEWER, ETC.)

d. ________ ROADWAY PAVEMENT, SHOULDERS AND TOE OF FILLS

e. ________ ANY DEVELOPMENT ADJACENT TO SITE, UP AND DOWNSTREAM

f. ________ EDGE OF FLOODPLAIN

g. ________ DRAINAGE COURSES AND DRAINAGE DITCHES

h. ________ WETLAND LIMITS

2. LEVELS

a. ________ CENTERLINE PROFILES OF NATURAL GROUND AND EXISTING HIGHWAY ( WHERE APPLICABLE ) ACROSS FLOODPLAIN

b. ________ SECTION UNDER BRIDGE

c. ________ SIZE, DEPTHS, AND INVERTS OF ALL CULVERTS AND STORM DRAINAGE SYSTEMS

d. ________ STREAM BED, NATURAL GROUND, AND WATER SURFACE PROFILE ( NORMAL ELEVATION AND ELEVATION AT DATE OF SURVEY ) UP AND DOWNSTREAM FOR A SUFFICIENT DISTANCE BEYOND LIMITS OF CONSTRUCTION. (EXTEND OUTLET DITCH PROFILES AS FAR AS NECESSARY TO REACH ADEQUATE CAPACITY )

e. ________ FLOODPLAIN CROSS-SECTIONS AS DEEMED NECESSARY FOR PERFORMING BACKWATER ANALYSIS

f. ________ ELEVATION OF ANY UP OR DOWNSTREAM DEVELOPMENT THAT WOULD BE CONSIDERED IN DESIGN ( EXAMPLE: ELEVATION OF HOUSES, BASEMENTS, YARDS, GARDENS, BARNS, AND PONDS )

g. ________ ELEVATION OF ANY DEBRIS OR OTHER HIGH WATER MARKS

3. SCOUR POTENTIAL: OBTAIN THE FOLLOWING FIELD INFORMATION IN ADDITION TO THE NORMAL BRIDGE CROSSING DATA

a. ________ WHAT IS THE STREAM BEDS AND FLOODPLAIN MATERIAL? IF SAND, IS IT FINE ,MEDIUM, OR COURSE?

b. ________ ARE THE STREAM BANKS STABLE? ARE THERE VISIBLE SLUMPS, VERTICAL BANKS, LEANING TREES, OR UNDERCUT BANKS?

AT EXISTING CROSSING SITES:

c. ________ OBTAIN A TYPICAL CHANNEL SECTION AT SUFFICIENT DISTANCE UP OR DOWNSTREAM BEYOND CROSSING AFFECTS

d. ________ OBTAIN BED PROFILE EXTENDING WELL BEYOND SCOUR AREA

e. ________ WHAT TYPE FOUNDATION DOES EXISTING STRUCTURE HAVE?

IF FOOTING IS VISIBLE, NOTE CONDITION

f. ________ OBSERVE GROUND CONDITIONS AROUND EXISTING PIERS AND SPILL THROUGH SLOPES. IS THERE INDICATION OF PREVIOUS SCOUR? IF SO IS DEPTH RECOGNIZABLE?

4. RECONNAISSANCE

a. ________ DRIFT POTENTIAL, SIZE AND QUANTITY. ( QUESTION SOURCES WHEN HIGH-WATER INFORMATION IS OBTAINED.)

b. ________ IDENTIFY CULTURE IN FLOODPLAIN FOR DETERMINATION OF FLOW RESISTANCE AND DISTRIBUTION ( ESTIMATE "N" VALUES )

c. ________ IDENTIFY DEVELOPMENT IN FLOODPLAIN THAT COULD BE AFFECTED BY BACKWATER, DOWNSTREAM EROSION OR REDUCTION OF FLOW

d. ________ IDENTIFY STORAGE AREAS SUCH AS PONDS, LAKES, ETC., FOR POSSIBLE ADJUSTMENT OF DISCHARGE RATES WHERE APPLICABLE

e. ________ REVIEW ADEQUACY OF DOWNSTREAM CHANNELS FOR CONVEYANCE OF INCREASED DISCHARGE RATES

f. ________ PHOTOGRAPHS OF SITE(S)

g. ________ LOCATION AND CLASSIFICATION OF WETLANDS

5. OBTAIN HISTORICAL H.W. INFORMATION SOURCES: ( NAMES AND ADDRESSES )

a. ________ LOCAL RESIDENTS

b. ________ BRIDGE MAINTENANCE PERSONNEL

c. ________ ROADWAY MAINTENANCE PERSONNEL

d. ________ FREQUENT ROAD USERS ( EX. MAILMAN, DELIVERY PEOPLE )

QUESTIONS:

a. ________ MAXIMUM H.W., WHEN IT OCCURRED?, WHAT DAMAGE OCCURRED?, PERIOD OF KNOWLEDGE OF PROVIDER

b. ________ OTHER LESSER FLOOD LEVELS, HOW OFTEN?

c. ________ YEARLY OCCURRENCE

d. ________ O.H.W. FOR POSSIBLE PERMIT

6. DATA ON UP AND DOWNSTREAM CROSSINGS

a. ________ SIZE

b. ________ RELATIVE LEVELS OF STRUCTURE AND ROADWAY

c. ________ PERFORMANCE ( FLOOD HISTORY )

HYDRAULIC STUDY

THE FOLLOWING INFORMATION IS TO BE COMPLETED BY THE DESIGN ENGINEER AT THE COMPLETION OF THE PROJECT DESIGN.

1. WHAT DESIGN FREQUENCIES WERE USED FOR DRAINAGE STRUCTURES? WHY?

2. WHAT ALTERNATES HAVE BEEN CONSIDERED FOR THE MAJOR DRAINAGE STRUCTURES

3. HAS AN ECONOMIC ANALYSIS BEEN MADE FOR ANY CROSSING DESIGNS?
HAS A LESSER DESIGN STANDARD BEEN CONSIDERED?

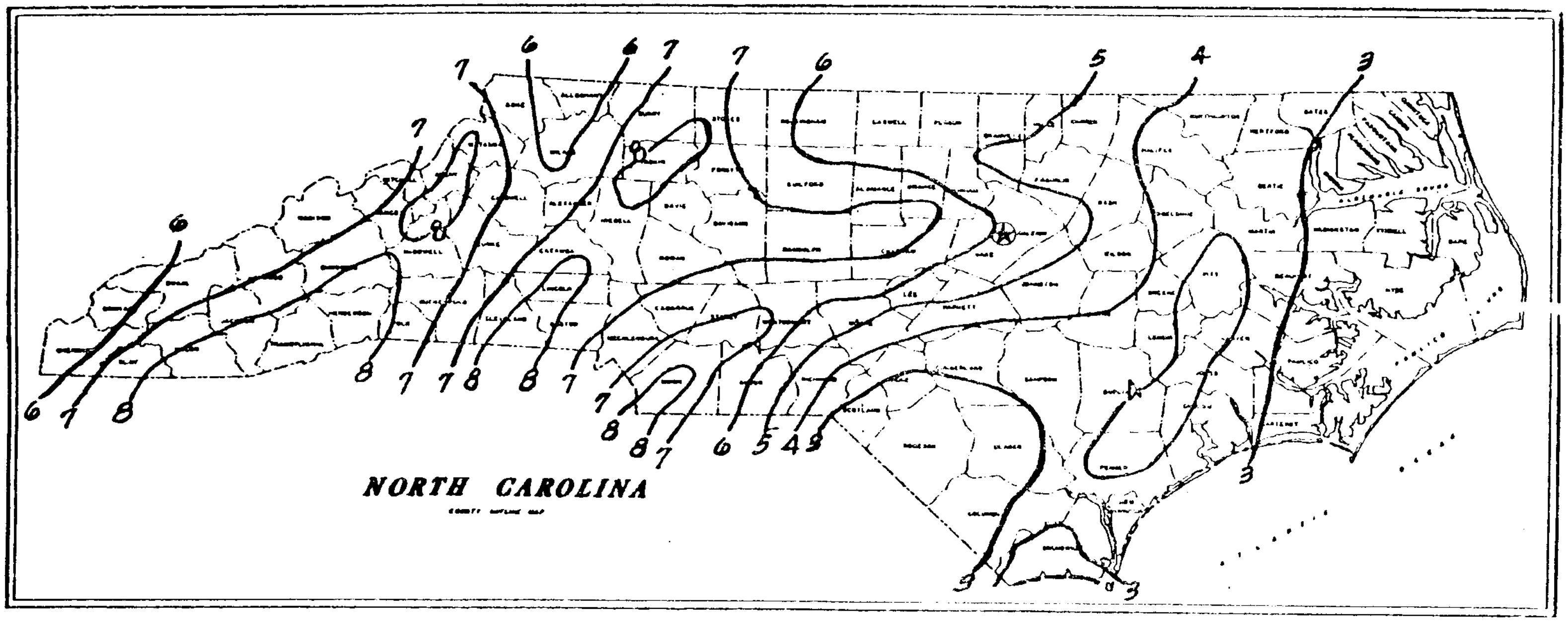
4. HAS PROPOSED STRUCTURE OR DESIGN BEEN CHANGED FROM WHAT WAS RECOMMENDED IN PLANNING REPORT? IF SO, HAS PLANNING BEEN NOTIFIED OF CHANGES?

5. HAVE INVERT GRADES OF STORM DRAINAGE SYSTEMS BEEN PLOTTED AND PROVISIONS MADE FOR UTILITY CONFLICTS?

6. HAVE WATER SURFACE PROFILES THROUGH STORM DRAINAGE SYSTEMS BEEN PLOTTED?

7. HAVE EVALUATIONS BEEN MADE OF OUTLET CHANNELS FOR POTENTIAL AFFECT OF PROJECT DEVELOPMENT?

APPROVED BY______________________________ DATE ______________




NORTH CAROLINA STATE HIGHWAY COMMISSION
HYDROGRAPHIC DEPT.
MAP OF HYDROLOGIC CONTOURS FOR USE IN DETERMINING
PROJECT DESIGN DISCHARGES

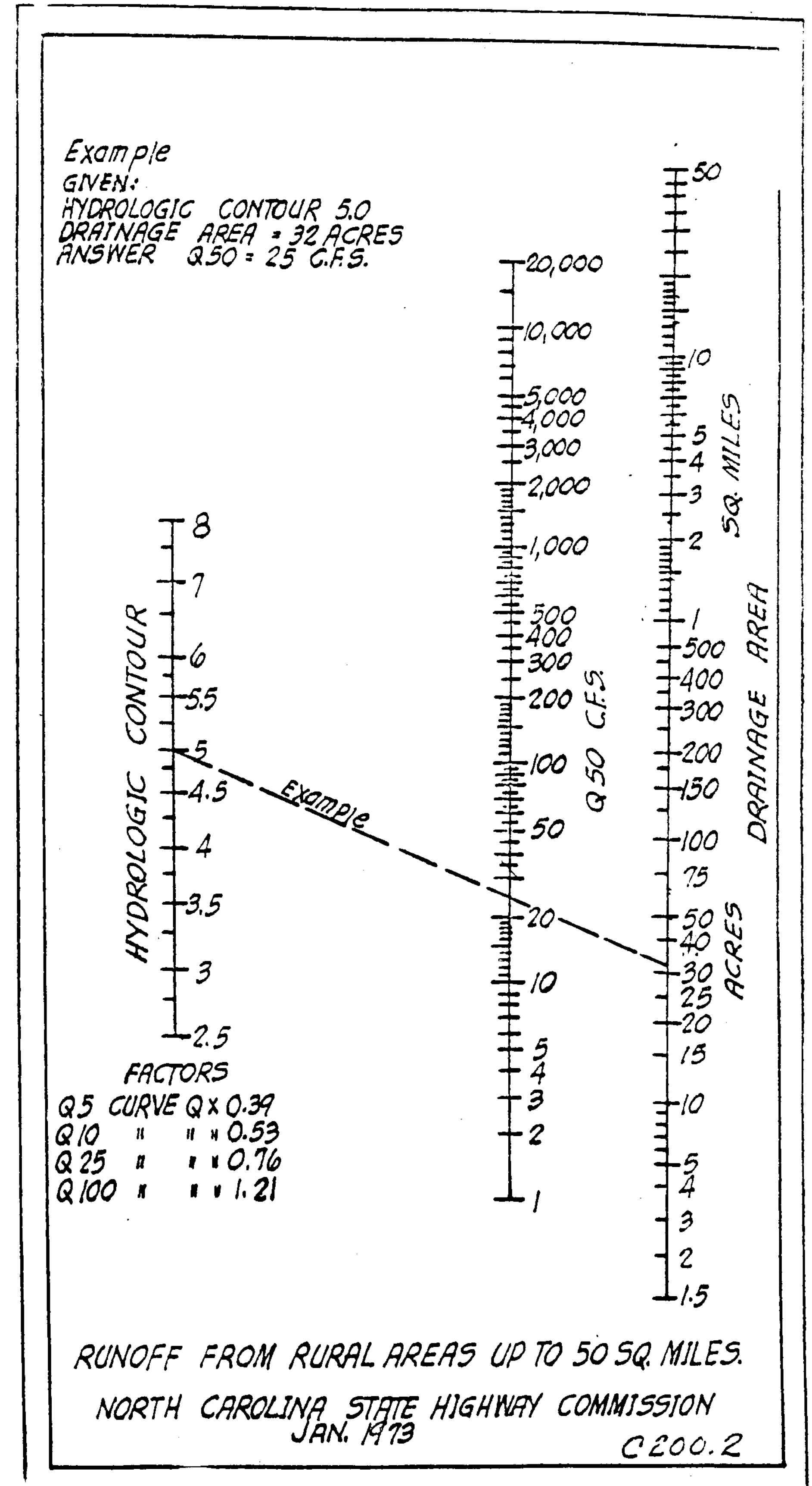
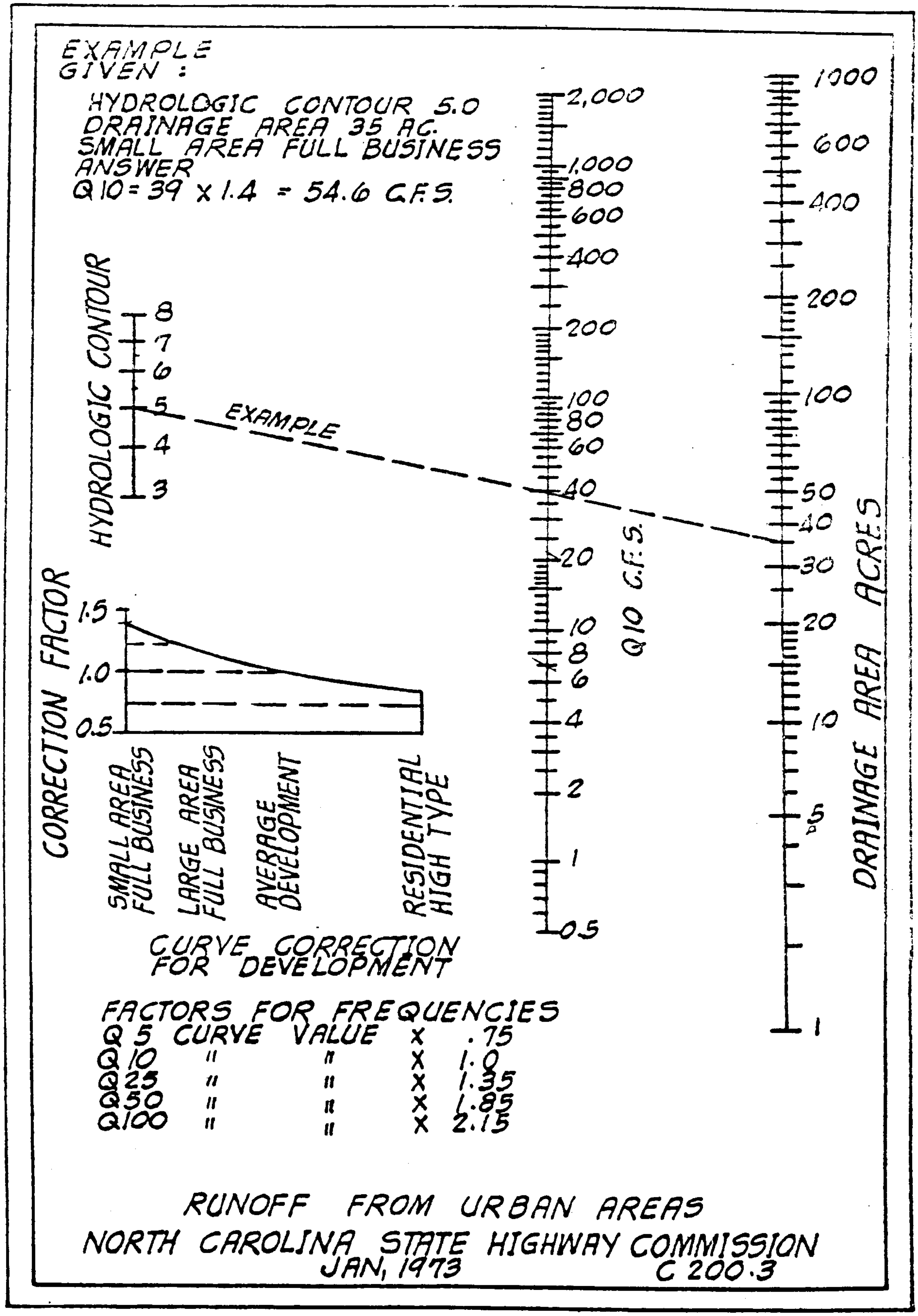
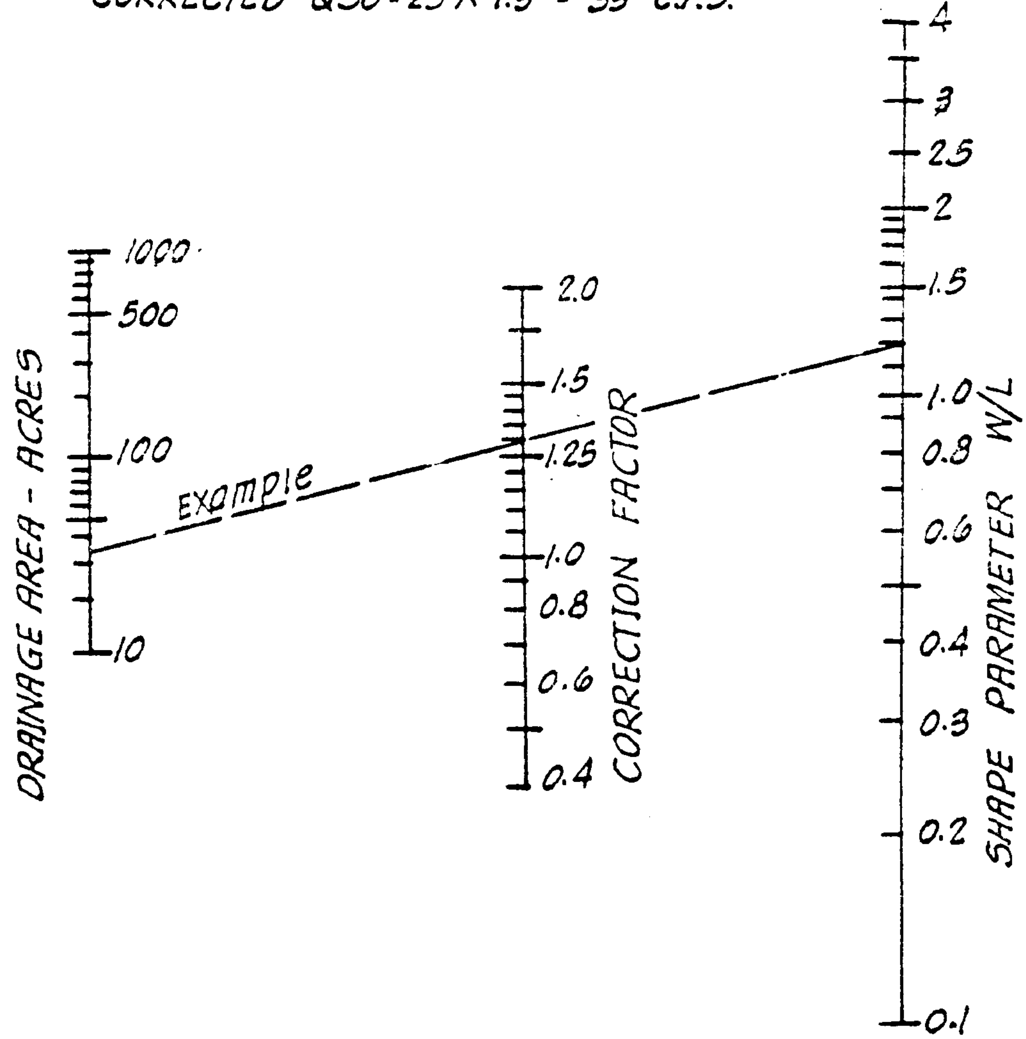

Example
GIVEN:
HYDROLOGIC CONTOUR 5.0
DRAINAGE AREA = 32 ACRES
ANSWER Q50 = 25 C.F.S.
HYDROLOGIC CONTOUR
8
7
6
5.5
5
4.5
4
3.5
3
2.5
Example
Q 50 C.F.S.
20,000
10,000
5,000
4,000
3,000
2,000
1,000
500
400
300
200
100
50
20
10
5
4
3
2
1
SQ. MILES
50
10
5
4
3
2
1
DRAINAGE AREA
ACRES
500
400
300
200
150
100
75
50
40
30
25
20
15
10
5
4
3
2
1.5
FACTORS
Q5 CURVE Q x 0.39
Q10 " " x 0.53
Q 25 " " x 0.76
Q 100 " " x 1.21
RUNOFF FROM RURAL AREAS UP TO 50 SQ. MILES.
NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN. 1973
C200.2

CHART C 200.2


EXAMPLE
GIVEN :
HYDROLOGIC CONTOUR 5.0
DRAINAGE AREA 35 AC.
SMALL AREA FULL BUSINESS
ANSWER
Q10 = 39 x 1.4 = 54.6 C.F.S.
HYDROLOGIC CONTOUR
8
7
6
5
4
3
EXAMPLE
2,000
1,000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
1
0.5
Q10 C.F.S.
1000
600
400
200
100
50
40
30
20
10
5
1
DRAINAGE AREA ACRES
CORRECTION FACTOR
1.5
1.0
0.5
SMALL AREA FULL BUSINESS
LARGE AREA FULL BUSINESS
AVERAGE DEVELOPMENT
RESIDENTIAL HIGH TYPE
CURVE CORRECTION FOR DEVELOPMENT
FACTORS FOR FREQUENCIES
Q 5 CURVE VALUE x .75
Q 10 " " x 1.0
Q 25 " " x 1.35
Q 50 " " x 1.85
Q 100 " " x 2.15
RUNOFF FROM URBAN AREAS
NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN, 1973
C 200.3

EXAMPLE
GIVEN :
DRAINAGE AREA 32 ACRES RURAL
W/L = 1.2
ANSWER FROM CHART 100.2 Q50 = 25 C.F.S.
CORRECTED Q50 = 25 X 1.3 = 33 C.F.S.




DRAINAGE AREA SHAPE PARAMETER
CORRECTION FACTORS

NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN, 1973

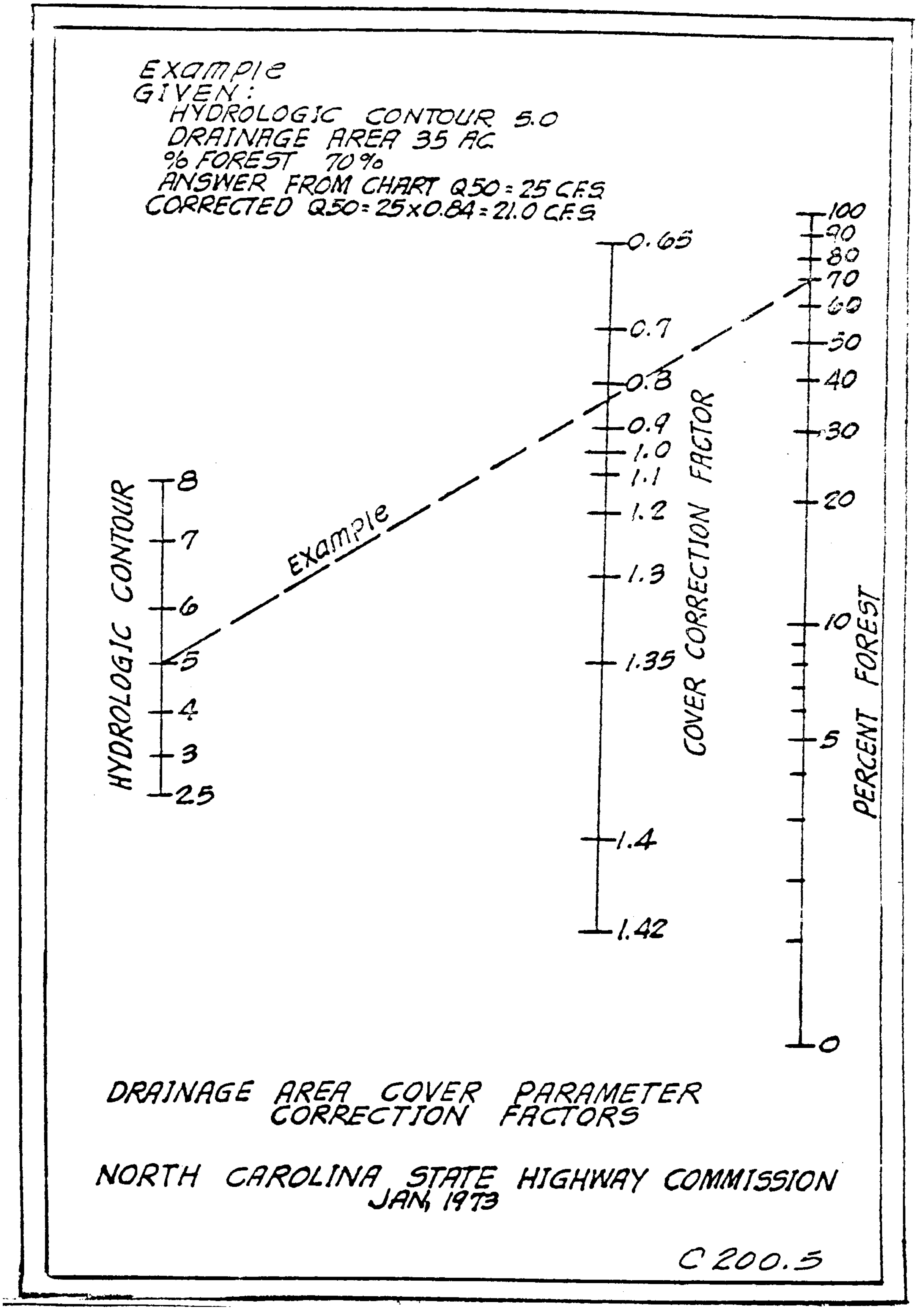
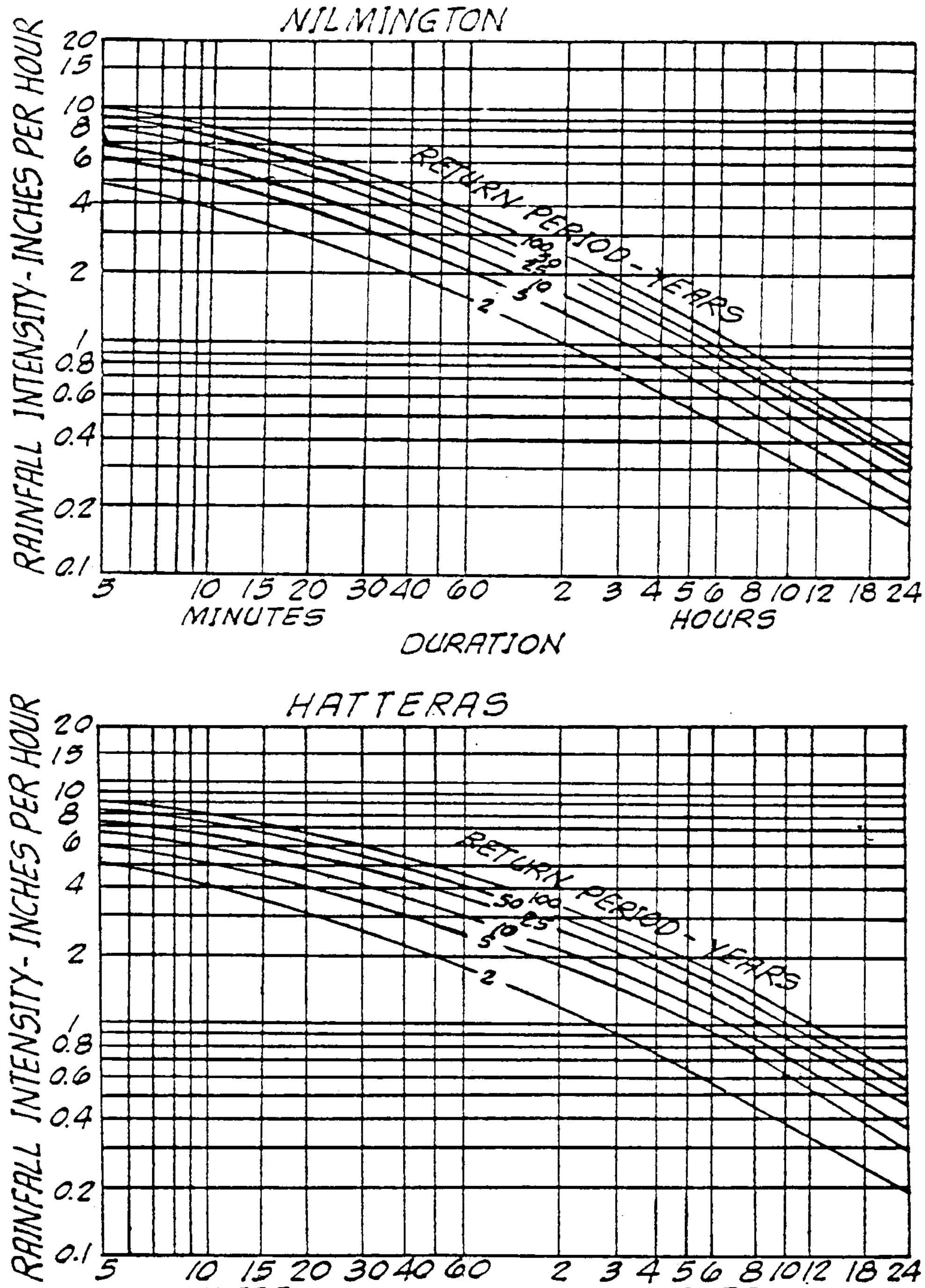
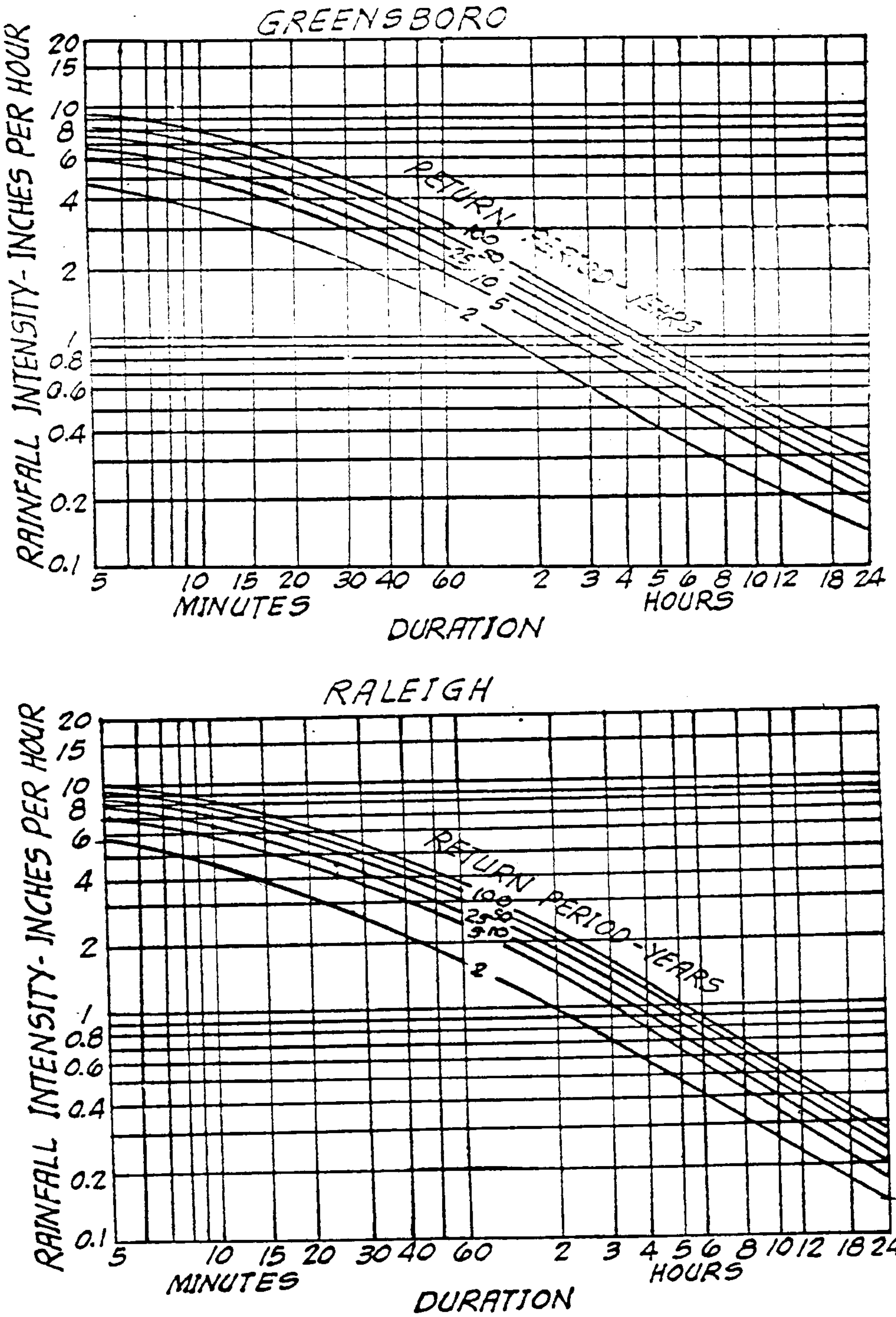

Example
GIVEN:
HYDROLOGIC CONTOUR 5.0
DRAINAGE AREA 35 AC
% FOREST 70%
ANSWER FROM CHART Q50 = 25 CFS
CORRECTED Q50 = 25 x 0.84 = 21.0 CFS
HYDROLOGIC CONTOUR
8
7
6
5
4
3
2.5
Example
COVER CORRECTION FACTOR
0.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.35
1.4
1.42
PERCENT FOREST
100
90
80
70
60
50
40
30
20
10
5
0
DRAINAGE AREA COVER PARAMETER CORRECTION FACTORS
NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN, 1973
C 200.5

CHART C200.5




RAINFALL INTENSITY DURATION CURVES
NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN, 1973

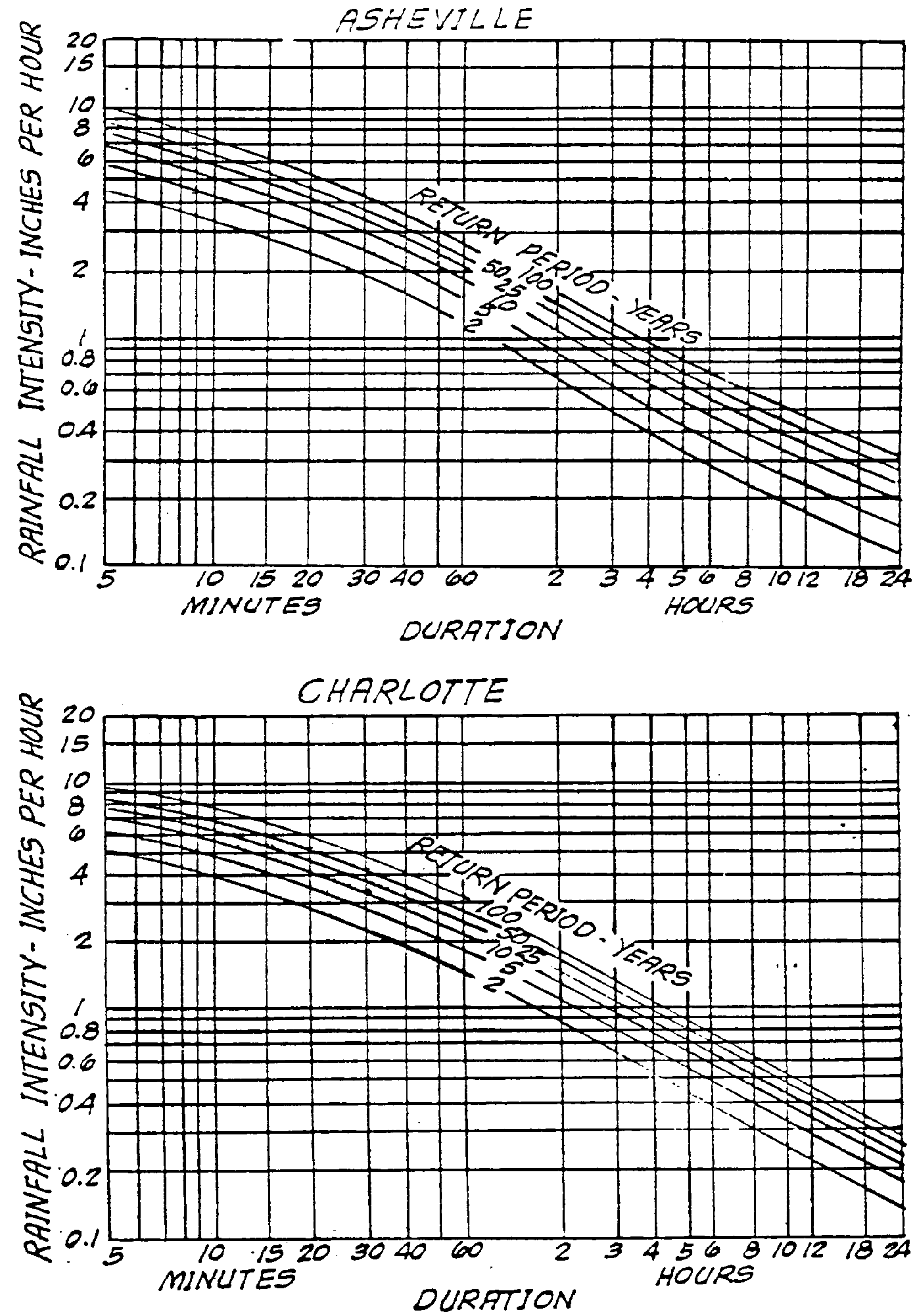
C200.7




RAINFALL INTENSITY DURATION CURVES
NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN, 1973

C200.8

CHART C 200.8




RAINFALL INTENSITY DURATION CURVES
NORTH CAROLINA STATE HIGHWAY COMMISSION
JAN, 1973

C200.9

# PRELIMINARY DESIGN AND ASSESSMENT OF STREAM CROSSINGS AND ENCROACHMENTS

COUNTY ________________________ PROJECT NUMBER _________________________

STREAM ________________________ ROUTE ___________________________________

ASSESSMENT PREPARED BY _______________________ DATE ___________________

## HYDROLOGIC EVALUATION

NEAREST GAGING STATION ON THIS STREAM ________ (NONE ___) __________

_____________________________________________________________________

ARE FLOOD STUDIES AVAILABLE ON THIS STREAM: ________________________

FLOOD DATA:
$Q_{10}$ ___ CFS EST. BKWTR. ___ FT. $Q_{25}$ ____ CFS EST. BKWTR. ___ FT.
$Q_{50}$ ___ CFS EST. BKWTR. ___ FT. $Q_{100}$ ___ CFS EST. BKWTR. ___ FT.
$Q_{500}$ ____ CFS OR OVERTOPPING CFS EST. BKWTR. ___ FT.

DRAINAGE AREA _____________ METHOD USED TO COMPUTE Q _______________

## PROPERTY RELATED EVALUATIONS

DAMAGE POTENTIAL: LOW __________ MODERATE __________ HIGH __________

COULD THIS BE SIGNIFICANTLY INCREASED BY PROPOSED

ENCROACHMENT: YES _____ NO _____

EXPLANATION: _______________________________________________________

_____________________________________________________________________

LIST BUILDINGS IN FLOOD PLAIN ___________ LOCATION ____________

FLOOR ELEVATION ________________________

UPSTREAM LAND USE ______________________

ANTICIPATE ANY CHANGE? _____________________________________

ANY FLOOD ZONING? (FIA STUDIES, ETC.) YES _____ NO _____

TYPE OF STUDY _____________________________________________________

BASE FLOOD ELEVATION ___________________________ (100 YEAR)

REGULATORY FLOODWAY WIDTH __________ (AS NOTED IN FIA STUDIES)
COMMENTS: ________________________________________________________

________________________________________________________

TRAFFIC RELATED EVALUATIONS

PRESENT YEAR _______ TRAFFIC COUNT _______ VPD % TRUCKS _________

DESIGN YEAR _______ TRAFFIC COUNT _______ VPD % TRUCKS _________

EMERGENCY ROUTE _______ SCHOOL BUS ROUTE _______ MAIL ROUTE _______

DETOUR AVAILABLE? ______ LENGTH OF DETOUR ______ MILES

DOES THE LEVEL OF TRAFFIC SERVICE OF AN EXISTING CROSSING VARY GREATLY FROM STANDARD DESIGN LEVELS? ____________________________________

__________________________________________________________________

IS THE TRAFFIC VOLUME, TYPE, USAGE SUCH TO WARRANT CONSIDERATION FOR VARIANCE FROM STANDARDS OR EXISTING LEVEL OF INTERRUPTION? _______

__________________________________________________________________

COMMENTS: ________________________________________________________

__________________________________________________________________

HIGHWAY AND BRIDGE (CULVERT) RELATED EVALUATIONS

NOTE ANY OUTSIDE FEATURES WHICH MIGHT AFFECT STAGE, DISCHARGE OR FREQUENCY.

LEVEES ______ AGGRADATION/DEGRADATION ______ RESERVOIRS ______

DIVERSIONS _______ DRAINAGE DISTRICT _______ NAVIGATION ______

BACKWATER FROM ANOTHER SOURCE _____________

EXPLANATION: ____________________________________________

__________________________________________________________

ROADWAY OVERFLOW SECTION (NONE ___) LENGTH ______ ELEVATION _______
EMBANKMENT: SOIL TYPE ____________ TYPE SLOPE COVER _____________
COMMENTS: ________________________________________________________

__________________________________________________________________

## ENVIRONMENTAL CONSIDERATIONS

LIST SPECIAL CONDITIONS OR CONSIDERATIONS WHICH AFFECT HYDRAULIC DESIGN (NONE _____)

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

## MISCELLANEOUS COMMENTS

IS THERE UNUSUAL SCOUR POTENTIAL? YES __ NO __PROTECTION NEEDED __

ARE BANKS STABLE? ___________________________ PROTECTION NEEDED __

DOES STREAM CARRY APPRECIABLE AMOUNT OF LARGE DEBRIS? ____________

COMMENTS:

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

## ALTERNATIVES

RECOMMENDED DESIGN ______________________________________________

DETOUR STRUCTURE ______________________________________________

LOW ROADWAY GRADE _____________________ DETOUR GRADE _____________

BRIDGE WATERWAY OPENING _______________ CULVERT OPENING ___________

WERE OTHER HYDRAULIC ALTERNATES CONSIDERED? YES ______ NO _______

DISCUSSION: ____________________________________________________

______________________________________________________________________

THIS SITE ASSESSMENT INDICATES THE DESIGN SHOULD FOLLOW:

(1) _____ NORMAL PROCESS

(2) _____ NORMAL PROCESS WITH SPECIAL SPECIFIC CONSIDERATION FOR

______________________________________________________

(3) _____ SPECIFIC DESIGN PROCESS WITH APPROPRIATE RISK/ECONOMIC EVALUATION ADDRESSING: _______________________________

# BRIDGE SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

I.D. No. ________ Project No. ________ Proj. Station ________

County ________ Bridge Over ________ Bridge Inv. No. ________

On Highway ________ Between ________ and ________

Recommended Structure ________

________

Recommended Width of Roadway ________ Skew ________

Recommended Location is ( Up, At, Down Stream from Existing Crossing). ________

Nearest Shipping Point ________ On ________ R.R., ____ Miles From Bridge

Bench Mark is ________

________ Elev. ________ Datum: ________

Temporary Crossing ________

USE THIS SPACE FOR PHOTOGRAPH
OF PROPOSED SITE, SHOWING CENTERLINE,
DIRECTION OF FLOW AND OTHER
IMPORTANT POINTS ON PHOTOGRAPH.

Designed by: ________ Date ________

Assisted by: ________

Project Engineer: ________

Reviewed by: ________

Stream ________ Bridge Inv. No. ________ I.D. No. ________ Project No. ________

## SITE DATA

Drainage Area ______________ Source __________________________ Character ________________

Stream Classification (Such as Trout, High Quality Water, etc.) ______________________________

Data on Existing Structure ______________________________________________________

_____________________________________________________ Waterway Opening __________

Data on Structures Up and Down Stream ____________________________________________

______________________________________________________________________________

______________________________________________________________________________

Design Control Elev. ______________________

Gage Station No. __________________________ Period of Records __________________________

Max. Discharge ______________________ c.f.s. Date __________________ Frequency ____________

Historical Flood Information:

Date _________ Elev. _______ Est. Freq. ______ Source ______________________________ Period of Knowledge ______

Date _________ Elev. _______ Est. Freq. ______ Source ______________________________ Period of Knowledge ______

Date _________ Elev. _______ Est. Freq. ______ Source ______________________________ Period of Knowledge ______

Historical Scour Info. : General ___________ Contraction ___________________ Local __________________

Channel Slope ___________ Source _______________________ Normal Water Surface Elev. ____________

Manning's n : Left O.B. ________ Channel _______ Right O.B. _______ Source ________________

Flood Study / Status ________________________________________________ Floodway Established? _____

Flood Study 100 yr. Discharge ________ c.f.s.; W.S. Elev. : With Floodway _______ Without Floodway ________

## DESIGN DATA

Hydrological Method ______________________________________________________________

Hydraulic Design Method ___________________________________________________________

Floods Evaluated:

| Freq. | Q | Elev. | Backwater | Bridge Opening Velocity |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Waterway Opening Provided Below: Design W.S. Elev. _________________, 100yr W.S. Elev. _________________

Average Channel Velocity (Design) ______________ Average Overbank Velocity (Design) _______________

Computed Scour : General _____________ Contraction ________________ Local ___________________

Is a Floodway Revision Required? _________________________________________________________

## INFORMATION TO BE SHOWN ON PLANS

| | | | | |
|---|---|---|---|---|
| Design: | Discharge ________ | c.f.s. | Frequency ________ | Elev. ________ |
| Base Flood: | Discharge ________ | c.f.s. | Frequency 100 yr. | Elev. ________ |
| Overtopping: | Discharge ________ | c.f.s. | Frequency ________ | Elev. ________ |

## ADDITIONAL INFORMATION AND COMPUTATIONS

# CULVERT SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

Project No. ____
I.D. No. ____
Stru. No. ____
Stream ____

I.D. No. ____ Project No. ____ Proj. Station ____

County ____ Stream ____ Stru. No. ____

On Highway ____ Between ____ and ____

Recommended Structure ____

____

Recommended Width of Roadway ____ Skew ____

Recommended Location is (Up, At, Down) Stream from Existing Crossing. ____

Bench Mark is ____

____ Elev. ____ Datum: ____

Temporary Crossing ____

USE THIS SPACE FOR PHOTOGRAPH
OF PROPOSED SITE, SHOWING CENTERLINE,
DIRECTION OF FLOW AND OTHER
IMPORTANT POINTS ON PHOTOGRAPH.

Designed by: ____ Date ____

Assisted by: ____

Project Engineer: ____

Reviewed by: ____

## SITE DATA

Drainage Area ______ Source ______ Character ______

Stream Classification (Such as Trout, High Quality Water, etc.) ______

Data on Existing Structure ______

Data on Structures Up and Down Stream ______

______

Gage Station No. ______ Period of Records ______

Max. Discharge ______ c.f.s Date ______ Frequency ______

Historical Flood Information:

Date ______ Elev. ______ Est. Freq. ______ Source ______ Period of Knowledge ______

Date ______ Elev. ______ Est. Freq. ______ Source ______ Period of Knowledge ______

Allowable HW Elev. ______ Normal Water Surface Elev. ______

Manning's n : Left O.B. ______ Channel ______ Right O.B. ______ Obtained From ______

Flood Study / Status ______ Floodway Established? ______

Flood Study 100 yr. Discharge ______ c.f.s.; W.S. Elev.: With Floodway ______ Without Floodway ______

## DESIGN DATA

Hydrological Method ______

Hydraulic Design Method ______

Design Tailwater : $Q_{10}$ ______ ; $Q_{25}$ ______ ; $Q_{50}$ ______ ; $Q_{100}$ ______ ; $Q_{500}$ ______

| Size & Type | Q | Ke | Inlet Control | | Outlet Control | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HW/D | H.W. | dc | $\frac{dc+D}{2}$ | $h_o$ | H | $LS_o$ | H.W. | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Is a Floodway Revision Required? ______

Outlet Velocity, ($V_{10}$) ______ Natural Channel Velocity, ($V_{10}$) ______

Required Outlet Protection ______

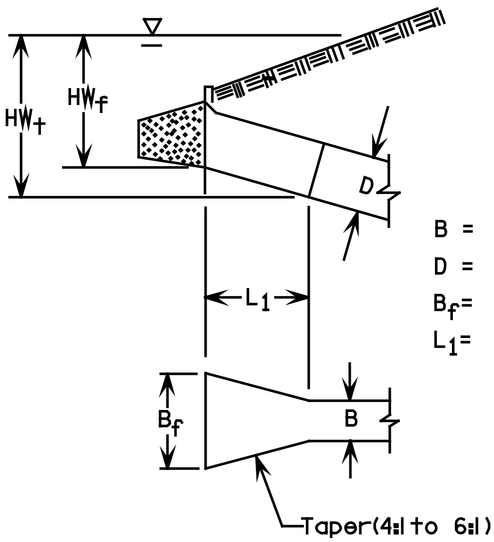
## INFORMATION TO BE SHOWN ON PLANS

Design: Discharge ______ c.f.s. Frequency ______ Elev. ______

Base Flood: Discharge ______ c.f.s. Frequency 100 yr. Elev. ______

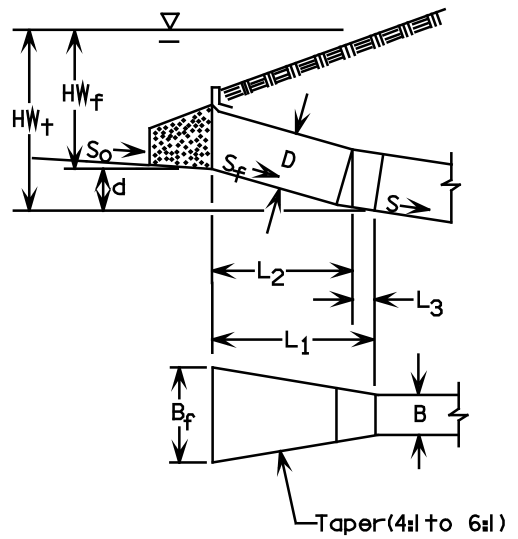
Overtopping: Discharge ______ c.f.s. Frequency ______ Elev. ______

## SIDE-TAPERED INLET




B =
D =
$B_f$=
$L_1$=

## SLOPE-TAPERED INLET




B =
D =
d =
$B_f$=
$L_1$=
$L_2$=
$L_3$=
$S_o$=
$S_f$=
S =

## ADDITIONAL INFORMATION AND COMPUTATIONS

# PIPE DATA SHEET

APPENDIX G

Date: _______ Sheet ______ of _____

Project Number: ____________________ I.D. No.: ________ County: _________________ Designed By: _________ Checked By: ___________

Station: ________

Skew: ________

Size/Type Pipe: ________

Type Enterence: ________

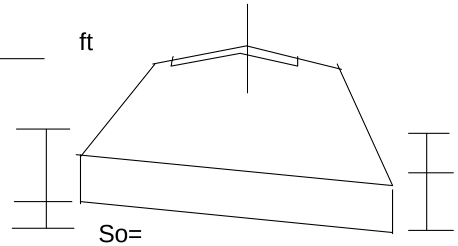
Direction of Flow: ________

Hydrological Method: ________

H.W. Control Elevation: ________

CL Elev.:__________ft

Shoulder Elev.: _________ ft




So= _______

Inlet Invert Elev.: _________ft L= _______ft Outlet Inv. Elev. ______ft

**Plan Summary Data**

Drainage Area: ________

Design Freq.: ________

Design Disch.: ________

Design H.W. Elev.: ________

Q100 Discharg.: ________

Q100 Elev.: ________

Overtopping Freq.: ________

Overtopping Disch.: ________

Overtopping Elev.: ________

**PIPE CULVERT ANALYSIS (English)**

rcp=.012, cmp=.024

n= ________

| **Channel Specs** Slope: | | Lt. Side Slope |
|---|---|---|
| Base= | n= | Rt. Side Slope |

| BARRELS | | FREQ | TW | Q | Nat. | Allow. | Inlet Control | | | Outlet Control | | | | | | | HW | $V_o$ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SIZE/TYPE | # | (yr) | ft | ft^3/s | H.W. | H.W. | HW/D | HW (ft) | | Ke | $d_c$ | $(d_c+D)/2$ | $h_o$ | H | $L*S_O$ | HW | ELEV. | Q/A | |
| | | | | | | | | | | | | | | | | | | | |
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5 - 5

## CORRUGATED STEEL PIPE - HEIGHT OF FILL LIMITATIONS

2" x " or 2-2/3" x " Corrugations - Riveted, Welded, or Helical Fabrication

| Size | Minimum Fill Over Top of pipe | 0.064" (16 Ga.) Cir. | 0.079" (14 Ga.) Cir. | 0.109" (12 Ga.) Cir. | 0.109" (12 Ga.) Elong. | 0.138" (10 Ga.) Cir. | 0.138" (10 Ga.) Elong. | 0.168" (8 Ga.) Cir. | 0.168" (8 Ga.) Elong. |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum Fill Above Top of Pipe | | | | | | | |
| 12" | 12" | 83 | 90 | | | | | | |
| 15" | 12" | 67 | 73 | 93 | | | | | |
| 18" | 12" | 55 | 67 | 70 | | | | | |
| 24" | 12" | 36 | 40 | 47 | | 57 | | | |
| 30" | 12" | | 31 | 35 | | 40 | | 50 | |
| 36" | 12" | | 20 | 30 | | 35 | | 40 | |
| 42" | 12" | | | 26 | 59 | 29 | 54 | 35 | 58 |
| 48" | 12" | | | 24 | 48 | 25 | 50 | 26 | 52 |
| 54" | 12" | | | 23 | 45 | 24 | 48 | 25 | 50 |
| 60" | 12" | | | | | 23 | 46 | 23 | 48 |
| 66" | 12" | | | | | 20 | 40 | 23 | 46 |
| 72" | 12" | | | | | 18 | 30 | 22 | 40 |
| 78" | 12" | | | | | | | 22 | 30 |
| 84" | 12" | | | | | | | 22 | 25 |

NOTE: WITH METHOD "B" INSTALLATION FILL HEIGHTS MAY BE INCREASED BY 50% OF TABLE VALUES

See Roadway Standards, Std. No. 300.02

5 - 6

## CORRUGATED STEEL PIPE ARCHES - HEIGHT OF FILL LIMITATIONS

| PIPE ARCH DIMENSION | MINIMUM COVER BELOW SUBGRADE | MINIMUM THICKNESS (t) | MAXIMUM FILL TOP OF PIPE FOR CORNER BEARING PRESSURE IN TONS/SQ. FT. | |
|---|---|---|---|---|
| Inches | Inches | | 2 Tons | 3 Tons |
| 17 X 13 | 18" | 0.064" | 16 | 23 |
| 21 X 15 | 18" | 0.064" | 15 | 22 |
| 24 X 18 | 18" | 0.064" | 13 | 19 |
| 28 X 20 | 18" | 0.064" | 12 | 18 |
| 35 X 24 | 18" | 0.079" | 11 | 17 |
| 42 X 29 | 18" | 0.079" | 10 | 15 |
| 49 X 33 | 18" | 0.109" | 10 | 14 |
| 57 X 38 | 18" | 0.109" | 10 | 14 |
| 64 X 43 | 18" | 0.109" | 10 | 14 |
| 71 X 47 | 18" | 0.138" | 10 | 15 |
| 77 X 52 | 18" | 0.168" | 10 | 15 |
| 83 X 57 | 18" | 0.168" | 9 | 14 |
| | | | | |

Heavier geges may be used where required for abrasion, corrosion or other factors, but not for additional fill on arches as corner pressures govern amount of fill.

## CORRUGATED ALUMINUM PIPE 5 - 7
3" X 1" CORRUGATION
MAXIMUM HEIGHT OF COVER LIMITS IN FEET

| SIZE | AREA | MINIMUM COVER | THICKNESS IN INCHES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | .075 | | .105 | | .135 | | .164 | |
| | | | CIR. | EL. | CIR. | EL. | CIR. | EL. | CIR. | EL. |
| 36 | 7.1 | 1 | 24 | 37 | 27 | 51 | 30 | 61 | 34 | 68 |
| 42 | 9.6 | 1 | | | 23 | 44 | 25 | 51 | 27 | 55 |
| 48 | 12.6 | 1 | | | 21 | 38 | 22 | 45 | 24 | 48 |
| 54 | 15.9 | 1 | | | 20 | 34 | 21 | 42 | 22 | 44 |
| 60 | 19.6 | 1 | | | 19 | 31 | 20 | 40 | 20 | 41 |
| 66 | 23.8 | 1 | | | 18 | 28 | 19 | 38 | 19 | 39 |
| 72 | 28.3 | 1 | | | 18 | 25 | 18 | 37 | 19 | 38 |
| 78 | 33.0 | 1 | | | 18 | 23 | 18 | 31 | 18 | 37 |
| 84 | 38.0 | 1.5 | | | 17 | 19 | 18 | 25 | 18 | 31 |
| 90 | 44.0 | 1.5 | | | 15 | | 17 | 20 | 18 | 25 |
| 96 | 50.0 | 1.5 | | | 12 | | 16 | | 17 | 21 |
| 102 | 57.0 | 2 | | | | | 14 | | 17 | |
| 108 | 64.0 | 2 | | | | | 11 | | 14 | |
| 114 | 71.0 | 2 | | | | | | | 12 | |
| 120 | 78.0 | 2 | | | | | | | 10 | |
| | | | | | | | | | | |

SEE ROADWAY STANDARDS, STANDARD NO. 300.02

## CORRUGATED STEEL PIPE - HEIGHT OF FILL LIMITATIONS 5 - 7A
3" X 1" CORRUGATIONS
RIVETED, WELDED, OR HELICAL FABRICATION

| SIZE | MINIMUM FILL OVER TOP | 0.079" (14 GAGE) | | 0.109" (12 GAGE) | | 0.138" (10 GAGE) | | 0.168" (8 GAGE) | |
|---|---|---|---|---|---|---|---|---|---|
| | | CIR. | EL. | CIR. | EL. | CIR. | EL. | CIR. | EL. |
| 36 | 1 | 47 | 60 | 58 | 88 | 70 | 106 | 82 | 118 |
| 42 | 1 | | | 44 | 76 | 51 | 91 | 59 | 101 |
| 48 | 1 | | | 36 | 66 | 41 | 80 | 46 | 88 |
| 54 | 1 | | | 31 | 59 | 35 | 71 | 38 | 76 |
| 60 | 1 | | | 28 | 58 | 31 | 62 | 33 | 66 |
| 66 | 1 | | | 26 | 48 | 30 | 58 | 32 | 64 |
| 72 | 1 | | | 25 | 44 | 28 | 56 | 30 | 60 |
| 78 | 1 | | | 24 | 41 | 26 | 52 | 28 | 56 |
| 84 | 1.5 | | | 22 | 36 | 24 | 46 | 28 | 56 |
| 90 | 1.5 | | | 20 | 33 | 22 | 43 | 26 | 53 |
| 96 | 1.5 | | | 17 | 31 | 20 | 40 | 25 | 49 |
| 102 | 2.0 | | | | | 19 | 38 | 23 | 46 |
| 108 | 2.0 | | | | | 18 | 35 | 21 | 42 |
| 114 | 2.0 | | | | | 16 | 32 | 19 | 38 |
| 120 | 2.0 | | | | | 15 | 29 | 18 | 36 |
| | | | | | | | | | |

Note: With method "B" installation, fill heights may be increased by 50%.
See Roadway Standards, Std. No. 300.02

5 - 8

CORRUGATED STEEL PIPE ARCHES - HEIGHT OF FILL LIMITATIONS
3" X 1" CORRUGATION
RIVETED, WELDED, OR HELICAL FABRICATION

| Equiv. Pipe Dia. | Pipe Arch Dimension | Minimum Cover | Minimum Gage | Maximum Fill Above Top of Pipe for Corner Pressure in Tons/sq. ft. | |
|---|---|---|---|---|---|
| | Inches | Inches | | 2 tons | 3 tons |
| 36 | 40 x 31 | 12 | 14(.079) | 14 | 21 |
| 42 | 46 x 36 | 12 | 12(.109) | 14 | 21 |
| 48 | 53 x 41 | 12 | 12(.109) | 14 | 21 |
| 54 | 60 x 46 | 12 | 12(.109) | 14 | 21 |
| 60 | 66 x 51 | 12 | 12(.109) | 14 | 21 |
| 66 | 73 x 55 | 12 | 12(.109) | 19 | 28 |
| 72 | 81 x 59 | 12 | 12(.109) | 17 | 26 |
| 78 | 87 x 63 | 12 | 12(.109) | 16 | 24 |
| 84 | 95 x 67 | 12 | 12(.109) | 15 | 22 |
| 90 | 103 x 71 | 18 | 12(.109) | 13 | 20 |
| 96 | 112 x 75 | 18 | 12(.109) | 13 | 18 |
| 102 | 117 x 79 | 18 | 10(.138) | 12 | 18 |
| 108 | 128 x 83 | 24 | 10(.138) | 11 | 16 |
| 114 | 137 x 87 | 24 | 10(.138) | 10 | 15 |
| 120 | 142 x 91 | 24 | 10(.138) | 10 | 15 |

Heavier gages may be used where required for durability or other factors,but not for additional fill,as corner pressures govern amount of fill.

5 - 9

CORRUGATED ALUMINUM PIPE

2" x½" or 2-2/3" x½" Corrugations - Riveted, Welded, or Helical Fabrication

| Size | Minimum Fill Over Top of pipe | 0.060" (16 Ga.) | | 0.079" (14 Ga.) | | 0.109" (12 Ga.) | | 0.138" (10 Ga.) | | 0.168" (8 Ga.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cir. | Elong. | Cir. | Elong. | Cir. | Elong. | Cir. | Elong. | Cir. | Elong. |
| Inches | | Maximum Fill Above Top of Pipe | | | | | | | | | |
| 12" | 12" | 45 | | 45 | | 77 | | | | | |
| 18" | 12" | 30 | | 30 | | 43 | | 50 | | 57 | |
| 24" | 12" | | | 22 | | 30 | | 34 | | 37 | |
| 30" | 12" | | | 18 | | 25 | | 27 | | 29 | |
| 36" | 12" | | | | | 23 | | 24 | | 25 | |
| 42" | 12" | | | | 25 | 23 | 42 | 23 | 46 | 23 | 46 |
| 48" | 12" | | | | | 21 | 29 | 22 | 37 | 22 | 44 |
| 54" | 12" | | | | | | 20 | 21 | 26 | 22 | 31 |
| 60" | 12" | | | | | | 15 | 19 | 19 | 22 | 24 |
| 66" | 12" | | | | | | | 14 | 14 | 17 | 17 |
| 72" | 12" | | | | | | | | | 13 | 13 |

With Method "B" installation increase fill heights allowable by 33%

## CORRUGATED ALUMINUM PIPE ARCHES

5 - 10

2" x* " or 2-1/2" x* " Corrugations - Riveted or Helical Fabrication

| PIPE ARCH DIMENSION | CORNER RADIUS | MINIMUM COVER BELOW SUBGRADE | MINIMUM THICKNESS (t) | MAXIMUM FILL TOP OF PIPE FOR CORNER BEARING PRESSURE IN TONS/SQ. FT. | |
|---|---|---|---|---|---|
| Inches | Inches | Inches | | 2 Tons | 3 Tons |
| 18 x 11 | 4-3/4 | 18" | 0.060" | 16 | 23 |
| 22 x 13 | 4-3/4 | 18" | 0.060" | 15 | 22 |
| 25 x 16 | 4-1/2 | 18" | 0.075" | 13 | 19 |
| 29 x 18 | 4-1/2 | 18" | 0.075" | 12 | 18 |
| 36 x 22 | 5 | 18" | 0.075" | 11 | 17 |
| 43 x 27 | 5-1/2 | 18" | 0.105" | 10 | 15 |
| 50 x 31 | 6 | 18" | 0.105" | 10 | 14 |
| 58 x 36 | 7 | 18" | 0.135" | 10 | 14 |
| 65 x 40 | 8 | 18" | 0.135" | 10 | 15 |
| 72 x 44 | 9 | 18" | 0.164" | 10 | 15 |

Heavier geges may be used where required for abrasion, corrosion or other factors, but not for additional fill on arches as corner pressures govern amount of fill.

## STRUCTURAL PLATE STEEL PIPE

6" x 2" Corrugations – **Bolted** Fabrications Maximum Fill Heights Over Top of Pipe

| SIZE | MIN. COVER OVER TOP OF PIPE | 0.109" 12 GAGE | | 0.138" 10 GAGE | | 0.168" 8 GAGE | | 0.188" 7 GAGE | | 0.218" 5 GAGE | | 0.249" 3 GAGE | | 0.280" 1 GAGE | | 0.280" * 1 GAGE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CIR. | ELONG | CIR. | ELONG | CIR. | ELONG | CIR. | ELONG | CIR. | ELONG | CIR. | ELONG | CIR. | ELONG | 6 Bolts ELONG | 8 Bolts ELONG |
| 60 | 12" | 42 | 42 | 61 | 62 | 70 | 81 | 76 | 93 | 86 | 112 | 96 | 132 | 106 | 144 | 184 | 220 |
| 66 | 12" | 38 | 38 | 49 | 58 | 60 | 74 | 64 | 85 | 72 | 102 | 80 | 120 | 83 | 130 | 168 | 198 |
| 72 | 12" | 35 | 35 | 38 | 51 | 50 | 67 | 53 | 77 | 59 | 93 | 65 | 108 | 71 | 118 | 157 | 181 |
| 78 | 12" | 32 | 32 | 36 | 47 | 44 | 62 | 46 | 71 | 51 | 83 | 55 | 100 | 60 | 109 | 143 | 159 |
| 84 | 12" | 30 | 30 | 35 | 44 | 39 | 57 | 41 | 66 | 45 | 75 | 49 | 95 | 52 | 102 | 131 | 145 |
| 90 | 12" | 28 | 28 | 33 | 40 | 35 | 53 | 37 | 61 | 40 | 72 | 43 | 84 | 45 | 91 | 122 | 133 |
| 96 | 12" | 26 | 26 | 31 | 38 | 33 | 50 | 34 | 58 | 36 | 70 | 39 | 78 | 41 | 82 | 115 | 124 |
| 102 | 24" | | | 29 | 36 | 31 | 47 | 32 | 54 | 34 | 65 | 36 | 72 | 38 | 75 | 107 | 117 |
| 108 | 24" | | | 27 | 34 | 29 | 45 | 30 | 51 | 32 | 62 | 34 | 68 | 35 | 70 | 102 | 112 |
| 114 | 24" | | | 26 | 33 | 28 | 42 | 29 | 48 | 31 | 58 | 32 | 63 | 34 | 65 | 96 | 107 |
| 120 | 24" | | | 25 | 31 | 27 | 40 | 28 | 46 | 29 | 56 | 30 | 60 | 33 | 62 | 72 | 104 |
| 126 | 24" | | | | | 26 | 37 | 26 | 44 | 27 | 52 | 29 | 58 | 30 | 59 | 86 | 100 |
| 132 | 24" | | | | | 25 | 36 | 25 | 42 | 26 | 50 | 28 | 56 | 29 | 58 | 83 | 98 |
| 138 | 24" | | | | | 24 | 34 | 25 | 39 | 25 | 48 | 27 | 54 | 28 | 55 | 79 | 94 |
| 144 | 24" | | | | | 24 | 33 | 25 | 38 | 25 | 46 | 26 | 52 | 27 | 54 | 76 | 92 |
| 156 | 24" | | | | | 23 | 31 | 23 | 35 | 24 | 43 | 25 | 50 | 26 | 52 | 70 | 85 |
| 168 | 24" | | | | | 23 | 28 | 23 | 33 | 23 | 40 | 24 | 47 | 25 | 50 | 65 | 78 |
| 180 | 24" | | | | | 22 | 27 | 22 | 31 | 23 | 37 | 23 | 44 | 24 | 48 | 61 | 73 |
| 192 | 24" | | | | | 22 | 25 | 22 | 29 | 23 | 35 | 23 | 41 | 23 | 45 | 57 | 69 |
| 204 | 36" | | | | | 22 | 23 | 22 | 27 | 22 | 33 | 22 | 39 | 23 | 42 | 54 | 65 |

* EXCELLENT BACKFILL 95% DENSITY

STRUCTURAL PLATE STEEL PIPE ARCHES
6"x2" Corrugation
18" Corner Radius

| Span | Rise | Area | Minimum Cover | Minimum Gage | Maximum Fill Height (ft.) for Corner Pressure 4000 lb/ft² | 6000 lb/ft² |
|---|---|---|---|---|---|---|
| 6'-1" | 4'-7" | 22 | 2' | 12 | 16 | 24 |
| 6'-4" | 4'-7" | 24 | 2' | 12 | 15 | 23 |
| 6'-9" | 4'-11" | 26 | 2' | 12 | 14 | 21 |
| 7'-0" | 5'-1" | 28 | 2' | 12 | 14 | 21 |
| 7'-3" | 5'-3" | 31 | 2' | 12 | 13 | 20 |
| 7'-8" | 5'-5" | 33 | 2' | 12 | 12 | 19 |
| 7'-11" | 5'-7" | 35 | 2' | 12 | 12 | 18 |
| 8'-2" | 5'-9" | 38 | 2' | 12 | 12 | 18 |
| 8'-7" | 5'-11" | 40 | 2' | 12 | 11 | 17 |
| 8'-10" | 6'-1" | 43 | 2' | 12 | 11 | 16 |
| 9'-4" | 6'-3" | 46 | 2' | 12 | 10 | 16 |
| 9'-6" | 6'-5" | 49 | 2' | 12 | 10 | 15 |
| 9'-9" | 6'-7" | 52 | 2' | 10 | 10 | 15 |
| 10'-3" | 6'-9" | 55 | 3' | 10 | 9 | 14 |
| 10'-8" | 6'-11" | 58 | 3' | 10 | 9 | 13 |
| 10'-11" | 7'-1" | 61 | 3' | 10 | 9 | 13 |
| 11'-5" | 7'-3" | 64 | 3' | 10 | 8 | 13 |
| 11'-7" | 7'-5" | 67 | 3' | 10 | 8 | 12 |
| 11'-10" | 7'-7" | 71 | 3' | 10 | 8 | 12 |
| 12'-4" | 7'-9" | 74 | 3' | 8 | 8 | 12 |
| 12'-6" | 7'-11" | 78 | 3' | 8 | 8 | 12 |
| 12'-8" | 8'-1" | 81 | 3' | 8 | 7 | 11 |
| 12'-10" | 8'-4" | 85 | 3' | 8 | 7 | 11 |
| 13'-5" | 8'-5" | 89 | 3' | 8 | 7 | 11 |
| 13'-11" | 8'-7" | 93 | 3' | 8 | 7 | 10 |
| 14'-1" | 8'-9" | 97 | 4' | 8 | 7 | 10 |
| 14'-3" | 8'-11" | 101 | 4' | 8 | 6 | 10 |
| 14'-10" | 9'-1" | 105 | 4' | 8 | 6 | 10 |
| 15'-4" | 9'-3" | 109 | 4' | 8 | 6 | 9 |
| 15'-6" | 9'-5" | 113 | 4' | 8 | 6 | 9 |
| 15'-8" | 9'-7" | 118 | 4' | 8 | 6 | 9 |
| 15'-10" | 9'-10" | 122 | 4' | 8 | 6 | 9 |
| 16'-5" | 9'-11" | 126 | 4' | 8 | 6 | 9 |
| 16'-7" | 10'-1" | 131 | 4' | 8 | 6 | 9 |

STRUCTURAL PLATE STEEL PIPE ARCHES
6"x2" Corrugation
31" Corner Radius

| Span | Rise | Area | Minimum Cover | Minimum Gage | Maximum fill Height (ft) for Corner Pressure 4000 lb/ft$^2$ | 6000 lb/ft$^2$ |
|---|---|---|---|---|---|---|
| 13'-3" | 9'-4" | 97 | 4' | 8 | 12 | 19 |
| 13'-6" | 9'-6" | 102 | 4' | 8 | 12 | 19 |
| 14'-0" | 9'-8" | 105 | 4' | 8 | 12 | 18 |
| 14'-2" | 9'-10" | 109 | 4' | 8 | 12 | 18 |
| 14'-5" | 10'-0" | 114 | 4' | 8 | 11 | 17 |
| 14'-11" | 10'-2" | 118 | 4' | 8 | 11 | 17 |
| 15'-4" | 10'-4" | 123 | 4' | 8 | 11 | 16 |
| 15'-7" | 10'-6" | 127 | 4' | 8 | 10 | 16 |
| 15'-10" | 10'-8" | 132 | 4' | 8 | 10 | 16 |
| 16'-3" | 10'-10" | 137 | 4' | 8 | 10 | 15 |
| 16'-6" | 11'-0" | 142 | 4' | 8 | 10 | 15 |
| 17'-0" | 11'-2" | 146 | 4' | 8 | 10 | 15 |
| 17'-2" | 11'-4" | 151 | 4' | 8 | 9 | 14 |
| 17'-5" | 11'-6" | 157 | 4' | 8 | 9 | 14 |
| 17'-11" | 11'-8" | 161 | 4' | 8 | 9 | 14 |
| 18'-1" | 11'-10" | 167 | 4' | 8 | 9 | 14 |
| 18'-7" | 12'-0" | 172 | 4' | 8 | 9 | 13 |
| 18'-9" | 12'-2" | 177 | 4' | 8 | 9 | 13 |
| 19'-3" | 12'-4" | 182 | 4' | 8 | 8 | 13 |
| 19'-6" | 12'-6" | 188 | 4' | 8 | 8 | 13 |
| 19'-8" | 12'-8" | 194 | 4' | 8 | 8 | 12 |
| 19'-11" | 12'-10" | 200 | 4' | 8 | 8 | 12 |
| 20'-5" | 13'-0" | 205 | 4' | 8 | 8 | 11 |
| 20'-7" | 13'-2" | 211 | 4' | 8 | 8 | 11 |

STRUCTURAL PLATE ALUMINUM PIPE ARCH
9"x2 1/2" Corrugations
28.8 Corner Radius

| Span | Rise | Area | Minimum Cover | Minimum Thickness | Maximum fill Height (ft) for Corner Pressure 4000 lb/ft$^2$ | 6000 lb/ft$^2$ |
|---|---|---|---|---|---|---|
| 5'-11" | 5'-4" | 25 | 2' | 0.100" | 24 | 32* |
| 6'-8" | 5'-7" | 29 | 2' | 0.100" | 22 | 29* |
| 7'-4" | 5'-11" | 34 | 2' | 0.100" | 20 | 26* |
| 8'-0" | 6'-2" | 39 | 2' | 0.100" | 18 | 24* |
| 8'-7" | 6'-6" | 45 | 2' | 0.100" | 17 | 22* |
| 9'-0" | 6'-8" | 48 | 2' | 0.100" | 16 | 21* |
| 9'-4" | 6'-10" | 50 | 2' | 0.125" | 17 | 20 |
| 10'-0" | 7'-1" | 56 | 3' | 0.125" | 16 | 19 |
| 10'-5" | 7'-3" | 60 | 3' | 0.125" | 15 | 18 |
| 11'-2" | 7'-6" | 66 | 3' | 0.125" | 14 | 17 |
| 11'-8" | 7'-10" | 73 | 3' | 0.125" | 13 | 16 |
| 12'-2" | 8'-0" | 76 | 3' | 0.150" | 13 | 19 |
| 12'-10" | 8'-3" | 83 | 3' | 0.150" | 12 | 18 |
| 13'-7" | 8'-7" | 91 | 3' | 0.150" | 11 | 17 |
| 14'-3" | 8'-10" | 98 | 4' | 0.150" | 11 | 16 |
| 14'-9" | 9'-2" | 107 | 4' | 0.150" | 10 | 16 |
| 15'-3" | 9'-4" | 111 | 4' | 0.150" | 10 | 15 |
| 16'-0" | 9'-7" | 119 | 4' | 0.150" | 10 | 14 |
| 16'-8" | 9'-11" | 128 | 4' | 0.150" | 9 | 12 |
| 16'-11" | 10'-1" | 132 | 4' | 0.150" | 9 | 12 |

* 0.125" Minimum Thickness Required

STRUCTURAL PLATE ALUMINUM PIPE
9"x2 1/2" Corrugation
Maximum Height of Cover Limits in Feet

| Size | Area | Minimum Cover | Thickness in Inches | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.10 | | 0.125 | | 0.15 | | 0.175 | | 0.20 | | 0.225 | | 0.25 | |
| | | | Cir. | El. | Cir. | El. | Cir. | El. | Cir. | El. | Cir. | El. | Cir. | El. | Cir. | El. |
| 72 | 28 | 1' | 24 | | 26 | 32 | 28 | 41 | 30 | 48 | 32 | 55 | 34 | 61 | 36 | 66 |
| 84 | 38 | 1.5' | 20 | | 23 | 27 | 24 | 35 | 25 | 41 | 26 | 47 | 28 | 52 | 29 | 57 |
| 96 | 50 | 1.5' | 18 | | 21 | 24 | 22 | 30 | 22 | 36 | 23 | 41 | 24 | 45 | 25 | 50 |
| 108 | 64 | 2' | | | 19 | 21 | 20 | 27 | 21 | 32 | 21 | 37 | 22 | 40 | 22 | 44 |
| 120 | 78 | 2' | | | 19 | 19 | 19 | 24 | 20 | 29 | 20 | 33 | 20 | 36 | 21 | 40 |
| 132 | 95 | 2' | | | | | 18 | 22 | 19 | 26 | 19 | 30 | 19 | 33 | 20 | 36 |
| 144 | 113 | 2.5 | | | | | 18 | 20 | 18 | 24 | 19 | 27 | 19 | 30 | 19 | 33 |
| 156 | 133 | 2.5 | | | | | 18 | 18 | 18 | 22 | 18 | 25 | 18 | 28 | 19 | 30 |
| 168 | 154 | 2.5 | | | | | 17 | | 18 | 20 | 18 | 23 | 18 | 26 | 18 | 28 |
| 180 | 177 | 2.5 | | | | | 16 | | 17 | 19 | 18 | 22 | 18 | 24 | 18 | 26 |

CORRUGATED ALUMINUM PIPE
3"x1" Corrugation
Maximum Height of Cover Limits in Feet

| Size | Area | Minimum Cover | Thickness in Inches | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | .075 | | .105 | | .135 | | .164 | |
| | | | Cir. | El. | Cir. | El. | Cir. | El. | Cir. | El. |
| 36 | 7.1 | 1 | 24 | 37 | 27 | 51 | 30 | 61 | 34 | 68 |
| 42 | 9.6 | 1 | | | 23 | 44 | 25 | 51 | 27 | 55 |
| 48 | 12.6 | 1 | | | 21 | 38 | 22 | 45 | 24 | 48 |
| 54 | 15.9 | 1 | | | 20 | 34 | 21 | 42 | 22 | 44 |
| 60 | 19.6 | 1 | | | 19 | 31 | 20 | 40 | 20 | 41 |
| 66 | 23.8 | 1 | | | 18 | 28 | 19 | 38 | 19 | 39 |
| 72 | 28.3 | 1 | | | 18 | 25 | 18 | 37 | 19 | 38 |
| 78 | 33 | 1 | | | 18 | 23 | 18 | 31 | 18 | 37 |
| 84 | 38 | 1.5 | | | 17 | 19 | 18 | 25 | 18 | 31 |
| 90 | 44 | 1.5 | | | 15 | | 17 | 20 | 18 | 25 |
| 96 | 50 | 1.5 | | | 12 | | 16 | | 17 | 21 |
| 102 | 57 | 2 | | | | | 14 | | 17 | |
| 108 | 64 | 2 | | | | | 11 | | 14 | |
| 114 | 71 | 2 | | | | | | | 12 | |
| 120 | 78 | 2 | | | | | | | 10 | |

## MASONRY DRAINAGE STRUCTURES QUANTITY - VOLUME BASIS 5-2D

Any masonry drainage structure which incorporates an opening for circular pipe exceeding 48 inches in diameter, or for pipe arch of any size, will be measured and paid for on a volume basis. The quantity of masonry to be paid for will be the number of cubic yards of cast-in-place concrete, brick, or precast masonry which has been incorporated into the structure. These quantities are provided in the Roadway Standard Drawings Manual.

## MINIMUM PIPE CLEARANCE REQUIREMENT FROM INVERT TO SUBGRADE 5-3

| | CLEARANCE DISTANCE | |
|---|---|---|
| Pipe Size (in.) | R. C. Pipe (ft.) | C. S. Pipe (ft.) |
| 15 | 2.4 | 2.3 |
| 18 | 2.7 | 2.6 |
| 24 | 3.3 | 3.1 |
| 30 | 3.8 | 3.6 |
| 36 | 4.3 | 4.1 |
| 42 | 4.9 | 4.6 |
| 48 | 5.4 | 5.1 |
| 54 | 6.0 | 5.6 |
| 60 | 6.5 | 6.1 |
| 66 | 7.0 | 6.6 |
| 72 | 7.6 | 7.1 |

NOTE: This is a minimum desirable clearance and can be reduced with Special Structural and/or Installation Provisions.

## MAXIMUM ALLOWABLE FILL HEIGHTS OVER REINFORCED CONCRETE PIPE 5-4

| | |
|---|---|
| Class III | All sizes 23 Ft. |
| Class IV | All sizes 32 Ft. |
| Class IV with Method B installation | All sizes 60 Ft. |
| Class V with Method B installation | All sizes 90 Ft. |

Use material thickness on all pipe except structural plate pipe. Use gage for structural plate pipe and on all pipe arches. Use Method "B" for R.C. Pipes under fills greater than 32 feet.

# INLET COMPUTATION SHEET

DATE: ________ SHEET ____ OF ____

I.D. NO. ________ PROJ. NO.: ______________ COUNTY: _______________________ DESIGNED BY: _______________

DESCRIPTION:__________________________________________ REACH: _____________________ CHECKED BY: _______________

| LOCATION | | | ROADWAY | | RUNOFF | | | | | | | INLET | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INLET NO. | STATION | ELEVATION | GRADE | CROSS SLOPE | DRAINAGE AREA | RUNOFF COEFF. | TIME OF CONC. | RAINFALL INTENSITY | DISCHARGE FROM D.A. | DISCHARGE CARRYOVER | TOTAL DISCHARGE | SPREAD | INTERCEPT | BYPASS | REMARKS |
| DES./ CONST. | | | | | D.A. | C | $T_C$ | I | $Q_{D.A.}$ | $Q_C$ | $Q_T=Q_{D.A.}+Q_C$ | | $Q_I$ | $Q_B$ | |
| | | | | | | | | | | | | | | | |
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# STORM DRAIN DESIGN COMPUTATIONS



[ SEE ALSO HYDRAULIC GRADE LINE SHEETS ]

DATE: SHEET ____ OF ____

I.D. NO. ____________ PROJ. NO. __________________ COUNTY: ____________________ DESIGNED BY: ______________

DESCRIPTION: ______________________________________________________________________ CHECKED BY: ______________

| LOCATION | | RUNOFF | | | | | | | | PIPE DESIGN | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FROM | TO | | | | TIME OF CONCENTRATION min. | | | | | INLET ELEV. | OUTLET ELEV. | | | | | | | |
| DES./ CONST. | DES./ CONST. | CUM. D.A. ac | SUM CA | PIPE L (ft) | INLET TIME | FLOW TIME | DESIGN TIME | INT I (in/hr) | DISCH. Q (cfs) | INV | INV | SLOPE ft/ft | DIA. in | MATERIAL | CAP. cfs | VEL. ft/s | UPSTREAM BOX DEPTH | REMARKS |
| | | | | | | | | | | | | | | | | | | |
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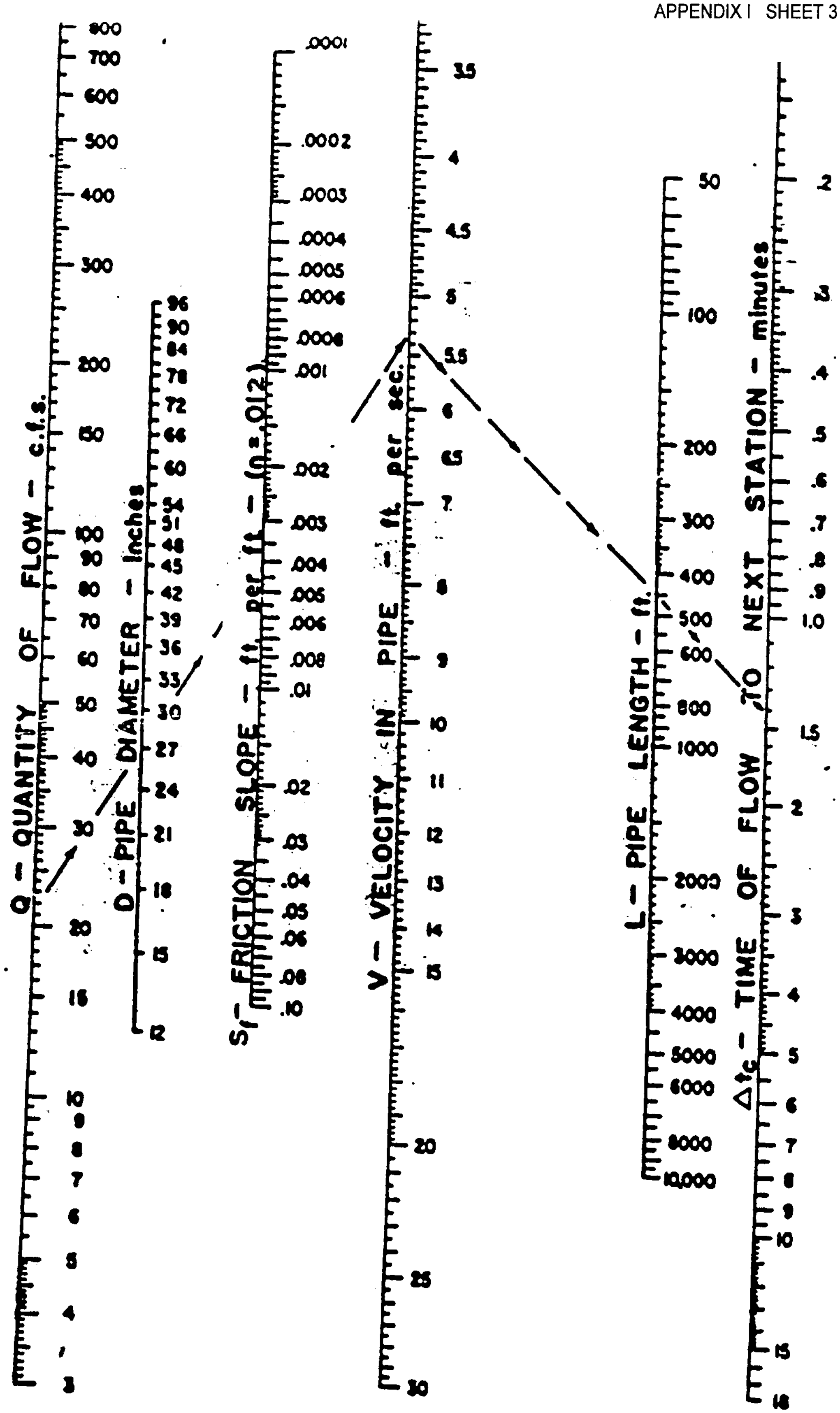
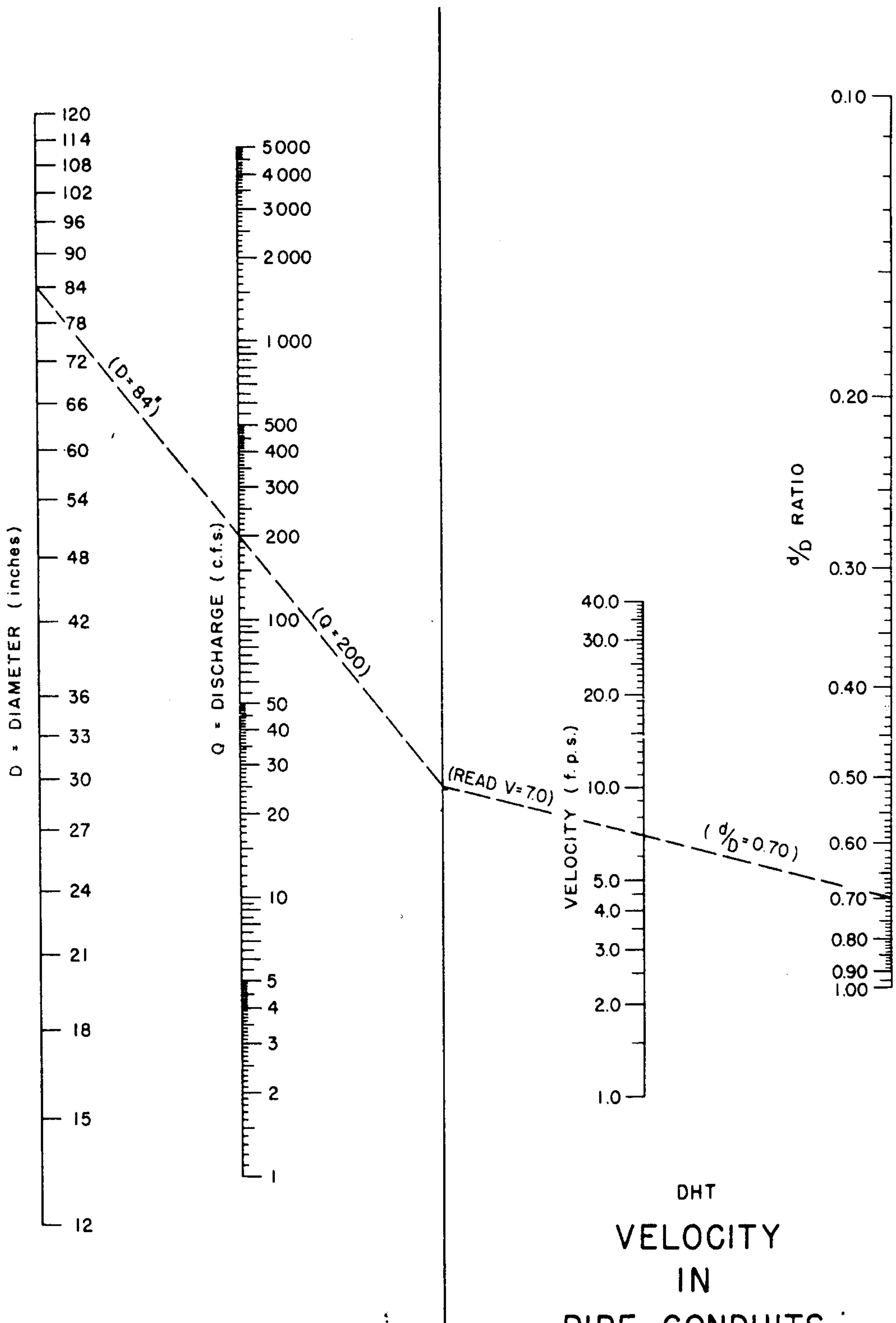



CONCRETE PIPE FLOW NOMOGRAPH




DHT

# VELOCITY IN PIPE CONDUITS

BASED ON

$Q = VA$

NOMOGRAPH H

6/90

# HYDRAULIC PROPERTIES - CIRCULAR PIPES

| Pipe Diam. (Inch) | A Pipe Area (sq. ft.) | R Hydraulic Radius (feet) | Value of K = 1.486/n x A x R $^{2/3}$ (n = 0.012) | Value of K = 1.486/n x A x R $^{2/3}$ (n = 0.024) |
|---|---|---|---|---|
| 8 | 0.349 | 0.167 | 13.1 | 6.5 |
| 10 | 0.545 | 0.208 | 23.7 | 11.9 |
| 12 | 0.785 | 0.250 | 38.6 | 19.3 |
| 15 | 1.227 | 0.313 | 70.0 | 35.0 |
| 18 | 1.767 | 0.375 | 113.8 | 56.9 |
| 21 | 2.405 | 0.438 | 171.7 | 85.8 |
| 24 | 3.142 | 0.500 | 245.1 | 122.5 |
| 27 | 3.976 | 0.563 | 335.5 | 167.8 |
| 30 | 4.909 | 0.625 | 444.4 | 222.2 |
| 33 | 5.940 | 0.688 | 572.9 | 286.5 |
| 36 | 7.069 | 0.750 | 722.6 | 361.3 |
| 42 | 9.621 | 0.875 | 1090 | 545.0 |
| 48 | 12.566 | 1.000 | 1556 | 778.1 |
| 54 | 15.904 | 1.125 | 2130 | 1065 |
| 60 | 19.635 | 1.250 | 2821 | 1411 |
| 66 | 23.758 | 1.375 | 3638 | 1819 |
| 72 | 28.274 | 1.500 | 4588 | 2294 |
| 78 | 33.183 | 1.625 | 5680 | 2840 |
| 84 | 38.485 | 1.750 | 6921 | 3460 |
| 90 | 44.179 | 1.875 | 8319 | 4159 |
| 96 | 50.265 | 2.000 | 9881 | 4940 |
| 102 | 56.745 | 2.125 | 11615 | 5807 |
| 108 | 63.617 | 2.250 | 13527 | 6763 |
| 114 | 70.882 | 2.375 | 15625 | 7812 |
| 120 | 78.540 | 2.500 | 17915 | 8958 |
| 126 | 86.590 | 2.625 | 20404 | 10202 |
| 132 | 95.033 | 2.750 | 23099 | 11550 |
| 138 | 103.869 | 2.875 | 26006 | 13003 |
| 144 | 113.097 | 3.000 | 29132 | 14566 |

# STORM DRAIN PIPE
# MAXIMUM CAPACITY TABLE

| (1) PIPE SIZE | (2) MAXIMUM CAPACITY |
|---|---|
| 12" | 6 |
| 15" | 9 |
| 18" | 13 |
| 24" | 25 |
| 30" | 43 |
| 36" | 64 |
| 42" | 90 |
| 48" | 120 |
| 54" | 160 |
| 60" | 200 |
| 66" | 250 |

(1) CONCRETE PIPE

(2) CAPACITY (c.f.s.) BASED ON INLET CONTROL FOR MAXIMUM DEPTH IN STANDARD CATCH BASIN

# HYDRAULIC GRADE LINE

SHEET ____OF____

DATE: ____________

ID NO. ____________ PROJECT: ____________________________ COUNTY: __________________ DESIGNED BY: ________________

DESCRIPTION: ________________________________________________________________________ CHECKED BY: ________________

| INLET OR JUNCT. NO.<br>DES. / CONST. | OUTLET W.S. ELEV. | $D_O$ | $Q_O$ | $L_O$ | HEAD LOSSES | | | | | INLET W.S. ELEV. | RIM ELEV. | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $H_f$ | $H_c$ | $H_e$ | $H_b$ | $H_t$ | | | |
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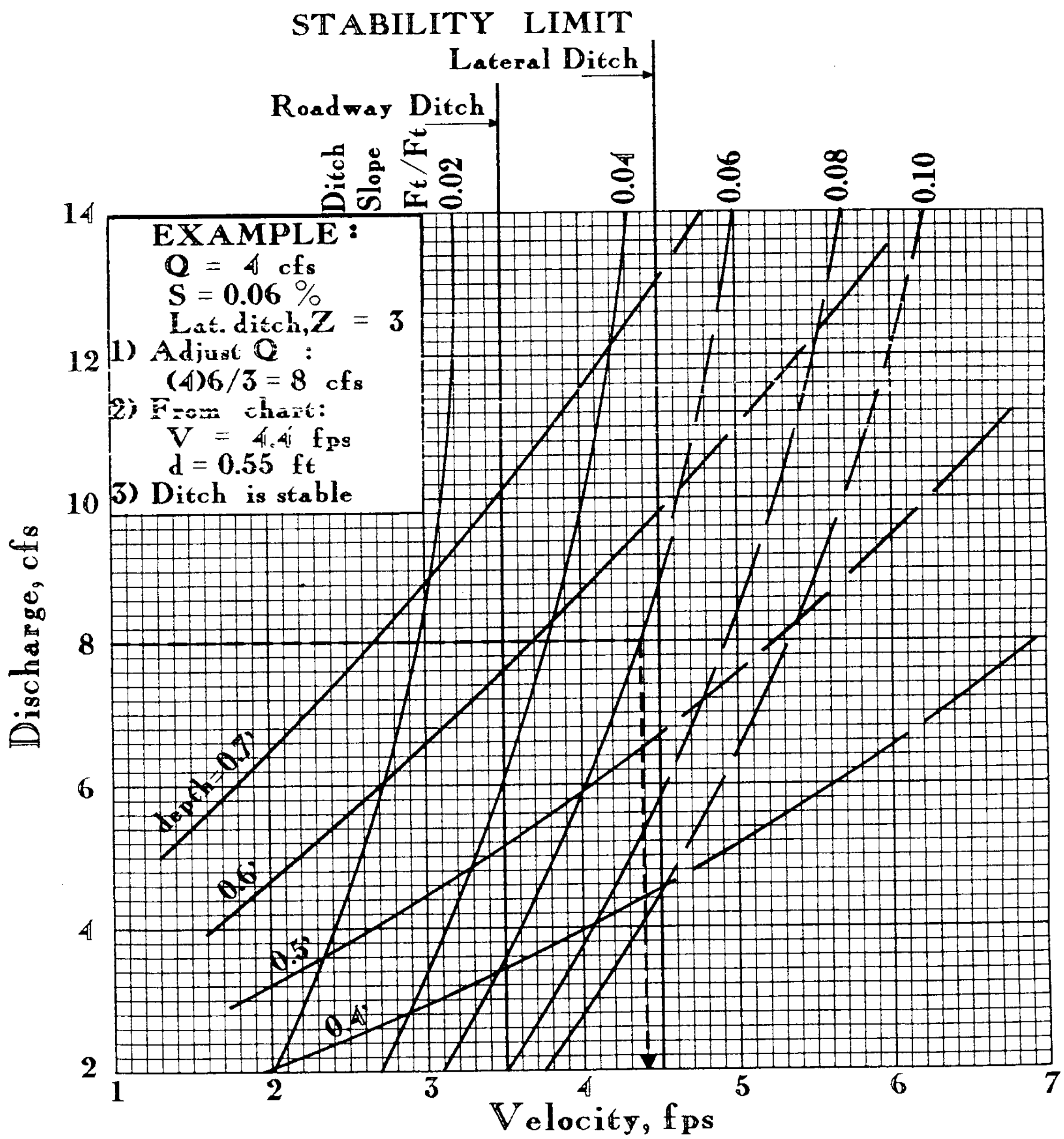
# 'V' DITCH WITH GRASS
# 6:1 SIDE SLOPES

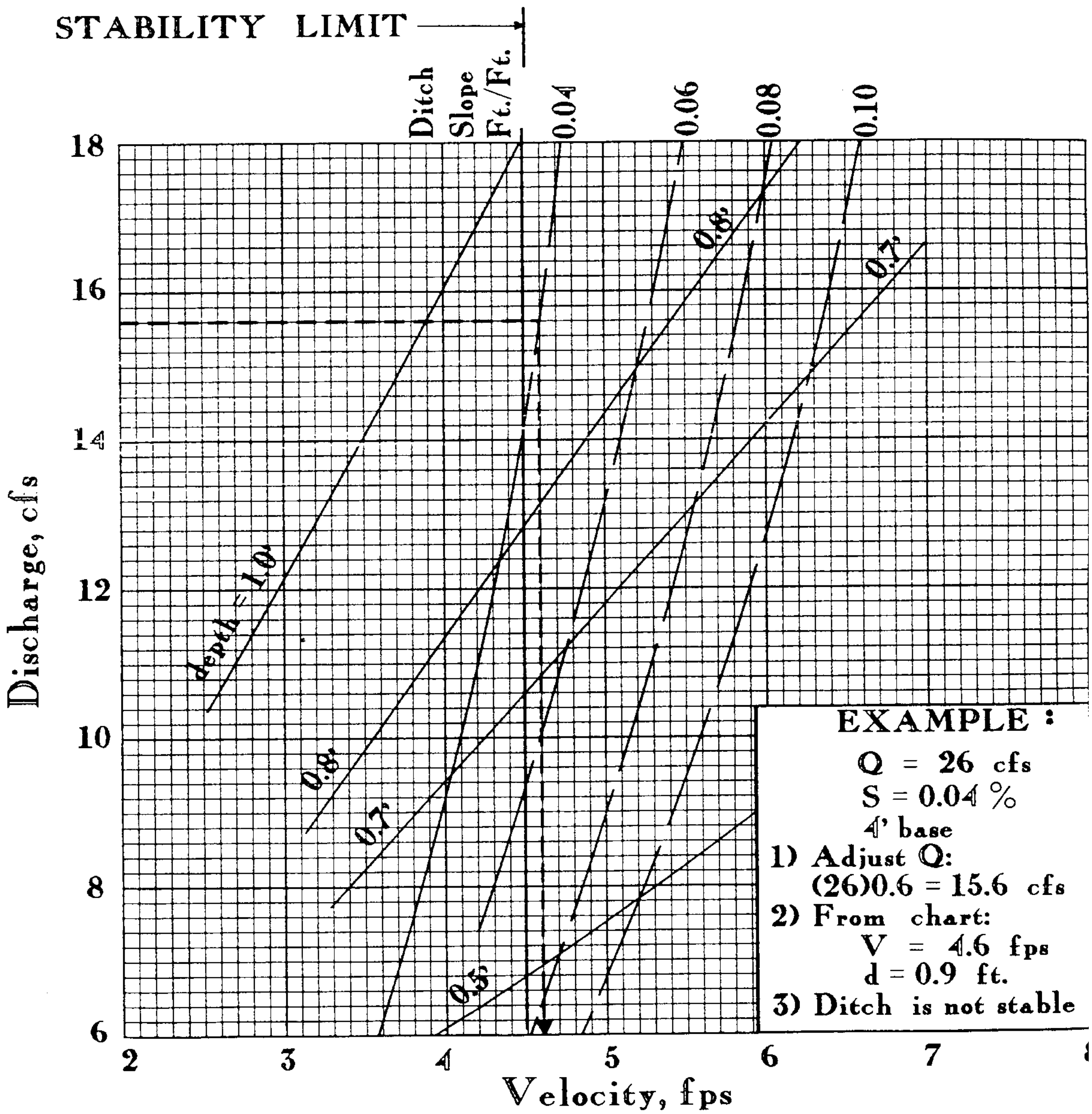
***For ditch with side slopes other than 6:1 multiply the discharge by a factor 6/Z, where Z is side slope***




## CHART 1

# 2 FT. BASE DITCH WITH GRASS
# 2:1 SIDE SLOPES

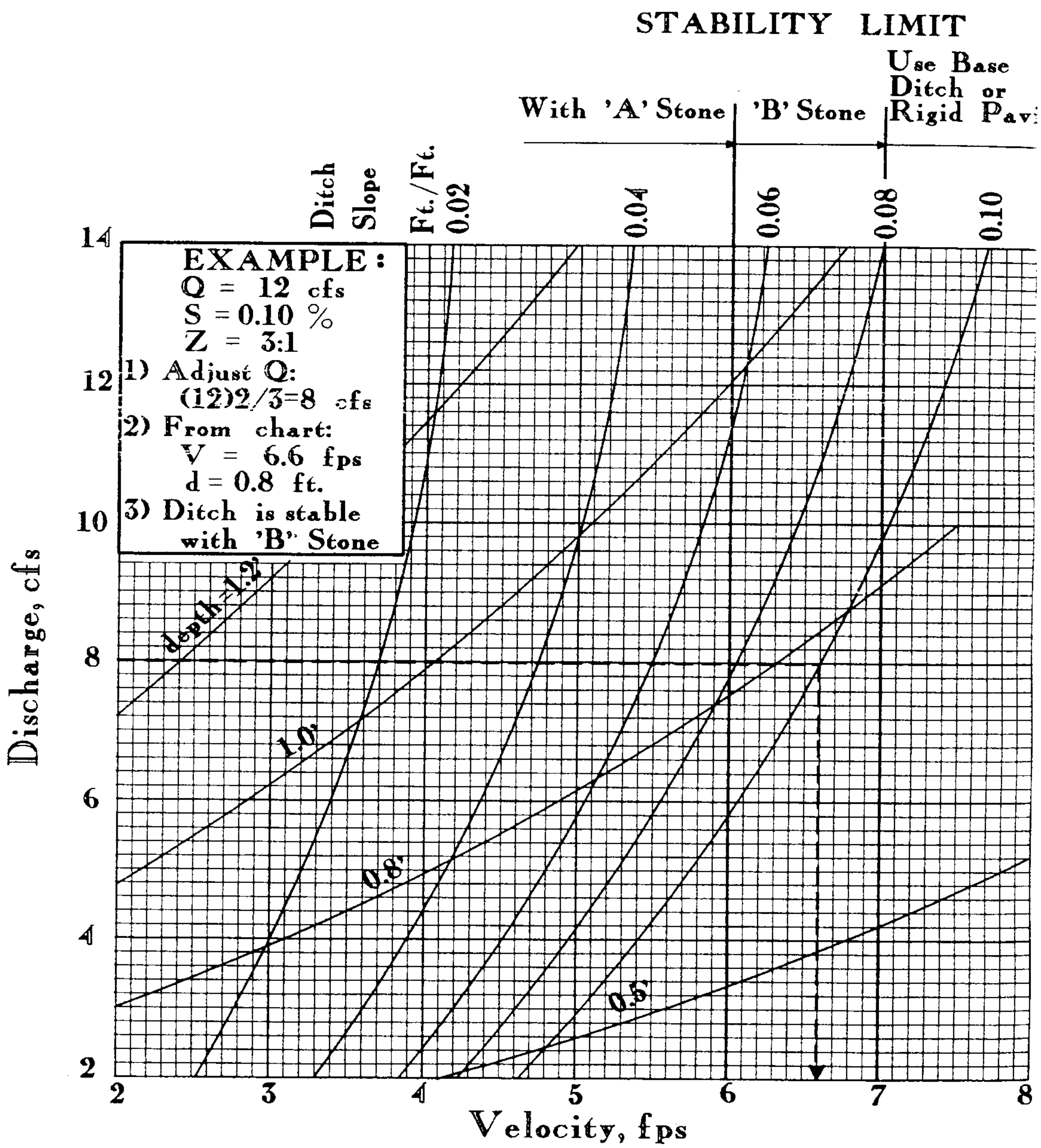
***For a 3 ft. base ditch, multiply discharge by 0.7***
***For a 4 ft. base ditch, multiply discharge by 0.6***




# CHART 2

# ‘V’ DITCH WITH RIP RAP
# 2:1 SIDE SLOPES

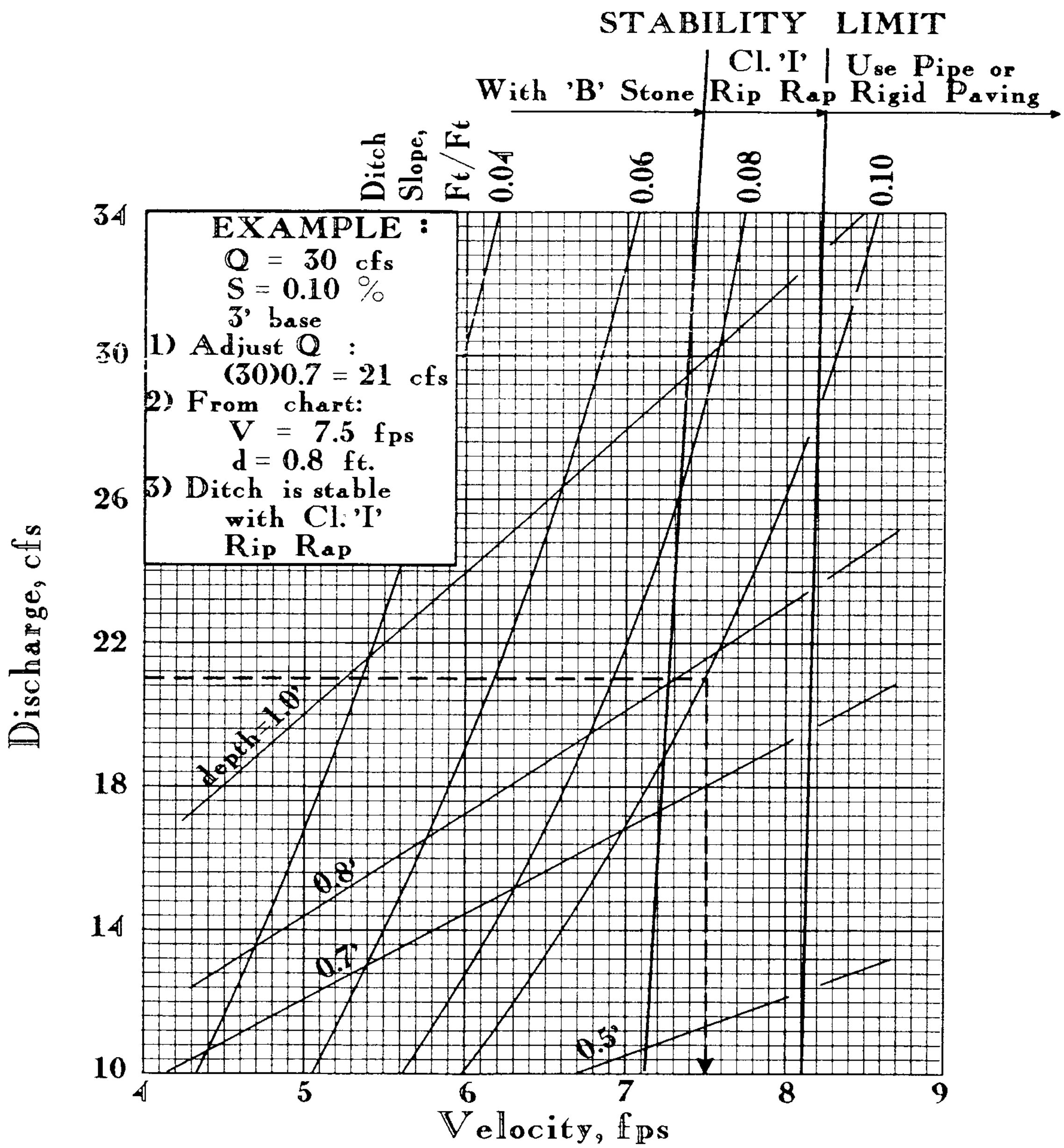
***For ditch with side slopes other than 2:1 multiply the discharge by a factor 2/Z, where Z is side slope***



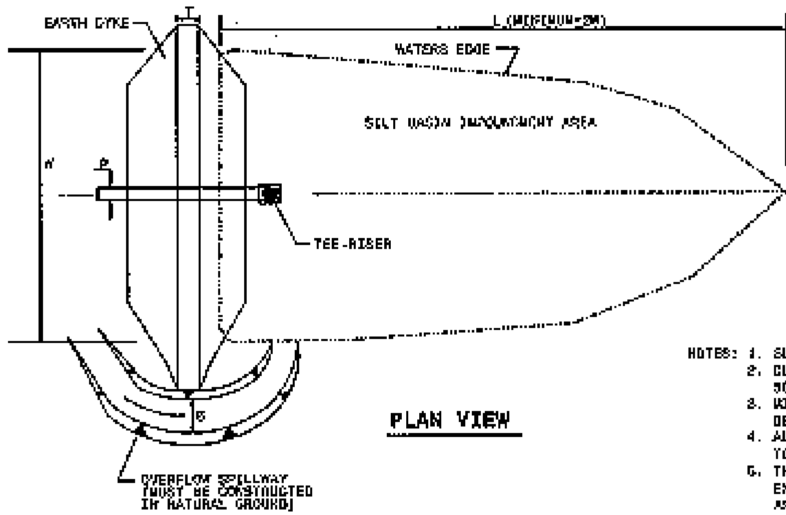

## CHART 3

# 2 FT. BASE DITCH WITH RIPRAP LINING 2:1 SIDE SLOPES

***For a 3 ft. base ditch, multiply by 0.7***
***For a 4 ft. base ditch multiply by 0.6***




# CHART 4




NOTES:
1. SURFACE AREA AND VOLUME ARE TO BE SITE SPECIFIC.
2. CLEAN OUT SEDIMENT WHEN STORAGE VOLUME REACHES 50% OF MIN. STORAGE VOLUME.
3. MINIMUM SURFACE AREA AND MINIMUM VOLUME ARE MEASURED BELOW THE TOP OF PRINCIPLE SPILLWAY (TOP OF RISER).
4. ALL DIMENSIONS OF BASIN WILL NOT REQUIRE CONSTRUCTION TO NEAT LINES.
5. THE EARTH DYKE MAY BE CONSTRUCTED ALONG ONE OR MORE SIDES. EXCAVATION MAY BE REQUIRED TO PROVIDE MINIMUM SURFACE AREA AND/OR MINIMUM STORAGE VOLUME.
6. THE DYKE SHALL BE CONSTRUCTED OF MATERIAL SUITABLE FOR AND MEETING ROADWAY EMBANKMENT SPECIFICATIONS.
7. TO FACILITATE DETERMINATION OF MAINTENANCE CLEANOUT REQUIREMENT A MARKER SHOULD BE PLACED IN THE BASIN INDICATING THE 50% VOLUME LEVEL.

| BASIN # | APPROX. STA. | P | H | T (min) | D* | E | F | B (min) | X (min) | Y (min) | $X_1$ (min) | $Y_1$ (min) | SURFACE AREA (min) | STORAGE VOLUME (min) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | in. | ft. | ft. | ft. | ft. | ft. | ft. | ft. | ft. | ft. | ft. | $ft.^2$ | $Yd.^3$ |
| | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | |

* SHALL NOT EXCEED 12'

HYDRAULICS ENGINEER

P.E.

SIGNATURE

SHEET 1 OF 2

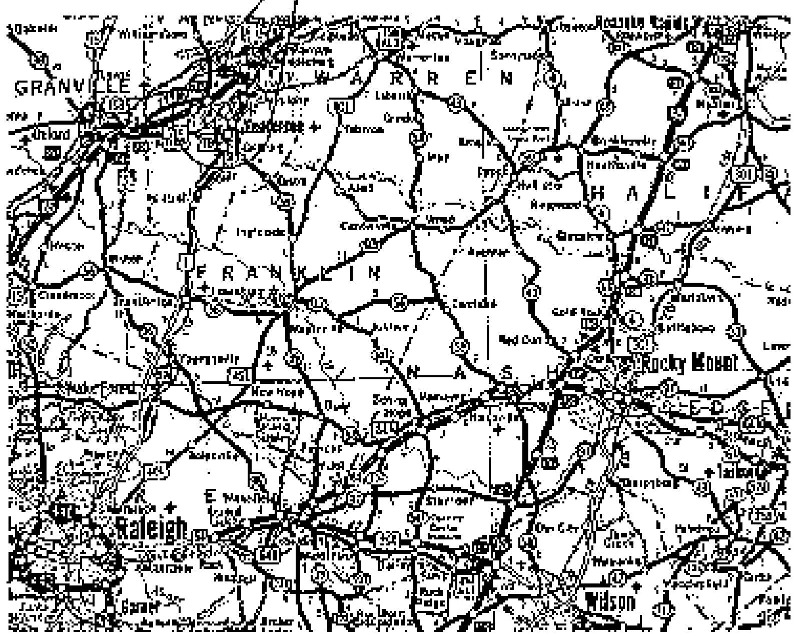
# SPECIAL DETAIL FOR TYPE "A" SILT BASIN

STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS
RALEIGH, N.C.

SAMPLE PERMIT DRAWINGS

# VICINITY MAP

SITE




N

N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

__________ COUNTY

PROJECT:

SHEET 1 OF 12 1/21/99

# LEGEND

- WLB — WETLAND BOUNDARY
- WLB — WETLAND
- F — DENOTES FILL IN WETLAND
- S — DENOTES FILL IN SURFACE WATER
- P — DENOTES FILL IN SURFACE WATER (POND)
- T — DENOTES TEMPORARY FILL IN WETLAND
- E — DENOTES EXCAVATION IN WETLAND
- TS — DENOTES TEMPORARY FILL IN SURFACE WATER
- DENOTES MECHANIZED CLEARING
- FLOW DIRECTION
- TB — TOP OF BANK
- WE — EDGE OF WATER
- C — PROP. LIMIT OF CUT
- F — PROP. LIMIT OF FILL
- PROP. RIGHT OF WAY
- NG — NATURAL GROUND
- PL — PROPERTY LINE
- TDE — TEMP. DRAINAGE EASEMENT
- PDE — PERMANENT DRAINAGE EASEMENT
- EAB — EXIST. ENDANGERED ANIMAL BOUNDARY
- EPB — EXIST. ENDANGERED PLANT BOUNDARY
- ▽ — WATER SURFACE

- LIVE STAKES
- BOULDER
- COIR FIBER ROLLS
- 5 — ADJACENT PROPERTY OWNER OR PARCEL NUMBER
- PROPOSED BRIDGE
- PROPOSED BOX CULVERT
- PROPOSED PIPE CULVERT

(DASHED LINES DENOTE EXISTNG STRUCTURES)

- SINGLE TREE
- WOODS LINE
- DRAINAGE INLET
- ROOTWAD
- VANE
- RIP RAP
- RIP RAP ENERGY DISSIPATOR BASIN
- BUFFER ZONE — BUFFER ZONE

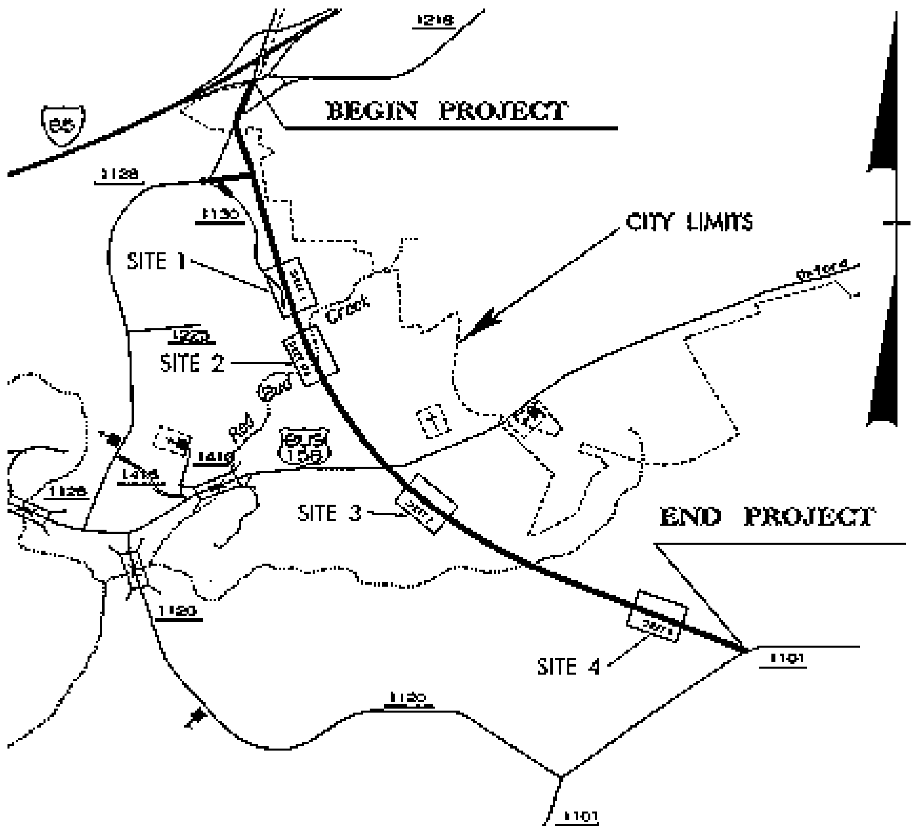
**N. C. DEPT. OF TRANSPORTATION**
**DIVISION OF HIGHWAYS**

________ **COUNTY**

**PROJECT:**

**SHEET 2 OF 12** **1/21/99**

# SITE MAP

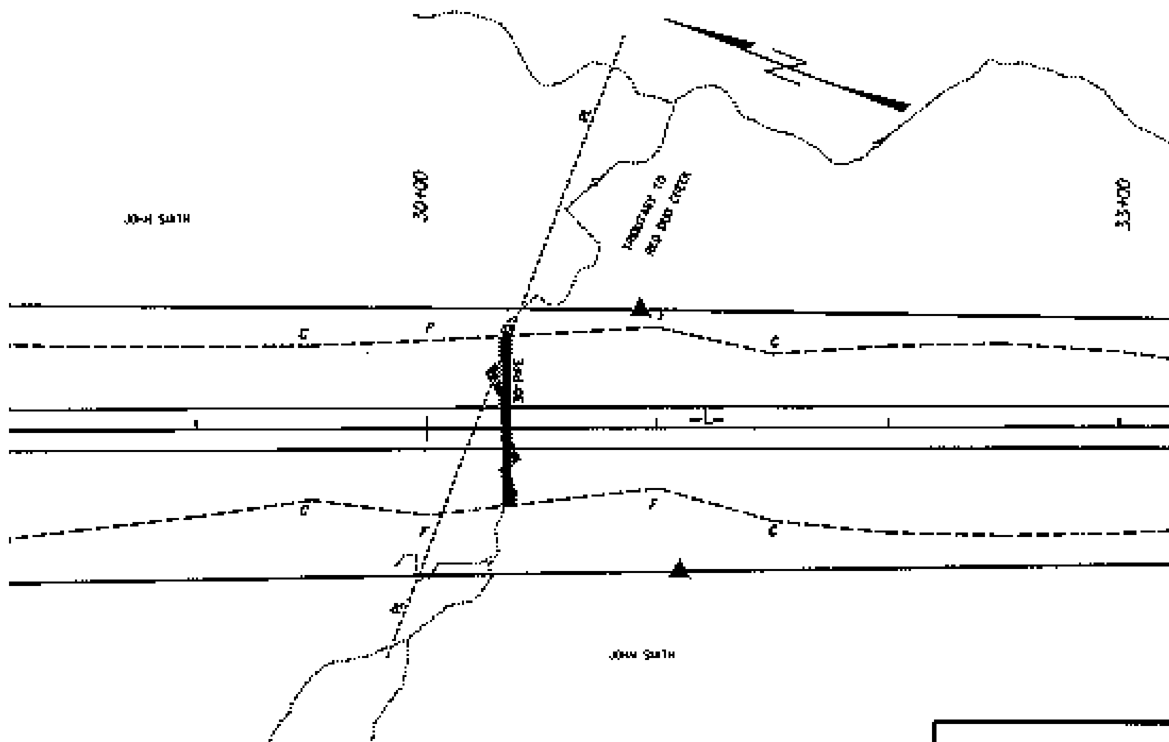



N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

__________ COUNTY

PROJECT:

SHEET 3 OF 12 1/21/99




# PLAN VIEW
## SITE 1

25' 0 50' SCALE

DENOTES FILL IN SURFACE WATERS

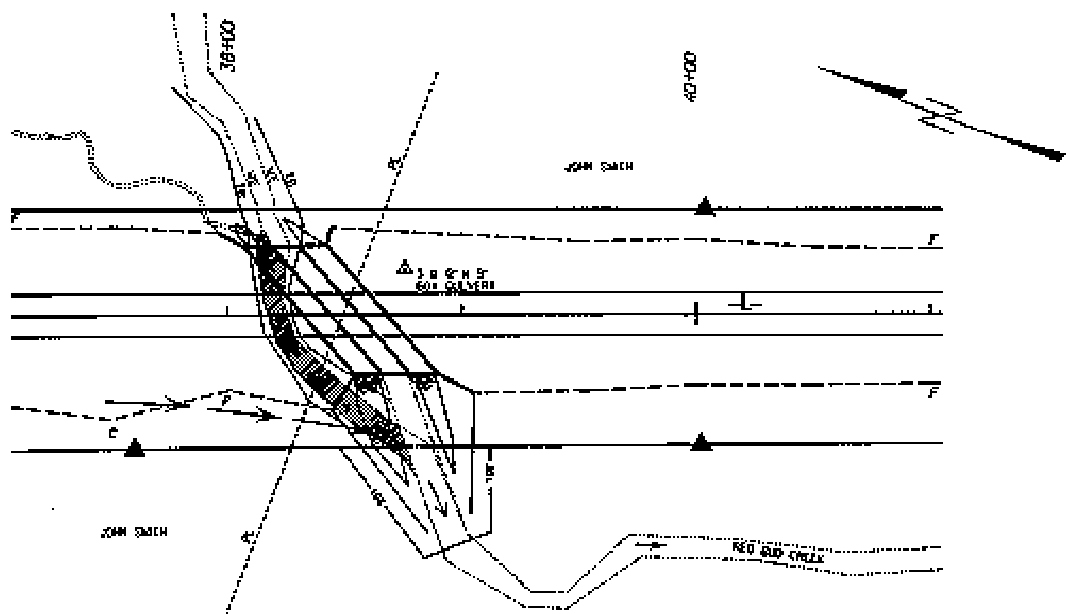
N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

__________ COUNTY

PROJECT:

SHEET 4 OF 12 1/21/99

APPENDIX L




# PLAN VIEW
# SITE 2

25' 0 50' SCALE

DENOTES FILL IN SURFACE WATERS

N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

______________ COUNTY

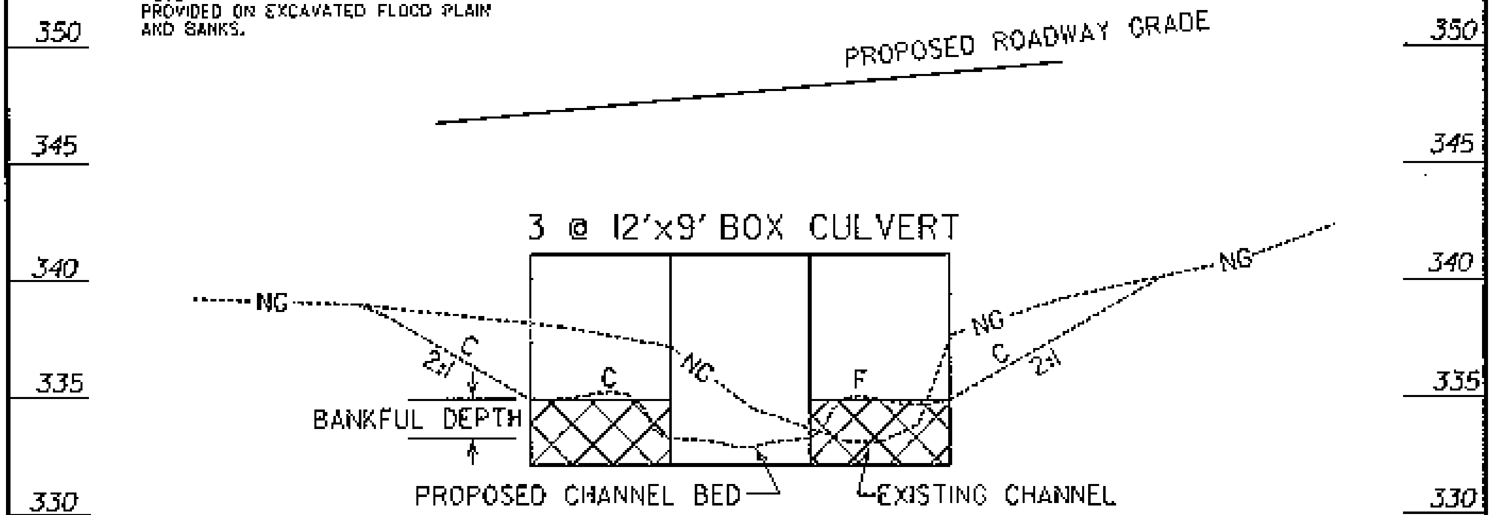
PROJECT:

△REV. 2/09/99

SHEET 5 OF 12 1/21/99

APPENDIX L

NOTES:
- BAFFLES PROVIDED AT INLET OF TWO BARRELS TO RETAIN NATURAL LOW FLOW CHANNEL WIDTH.
- INVERT OF CULVERT SET 1FOOT BELOW STREAM TO ALLOW FORMATION OF NATURAL BED.
- VEGETATIVE STABILIZATION AND PLANTINGS PROVIDED ON EXCAVATED FLOOD PLAIN AND BANKS.




# PROFILE VIEW
# SITE 2

5' 0 10' HORIZONTAL SCALE

2.5' 0 5' VERTICAL SCALE

BAFFLE

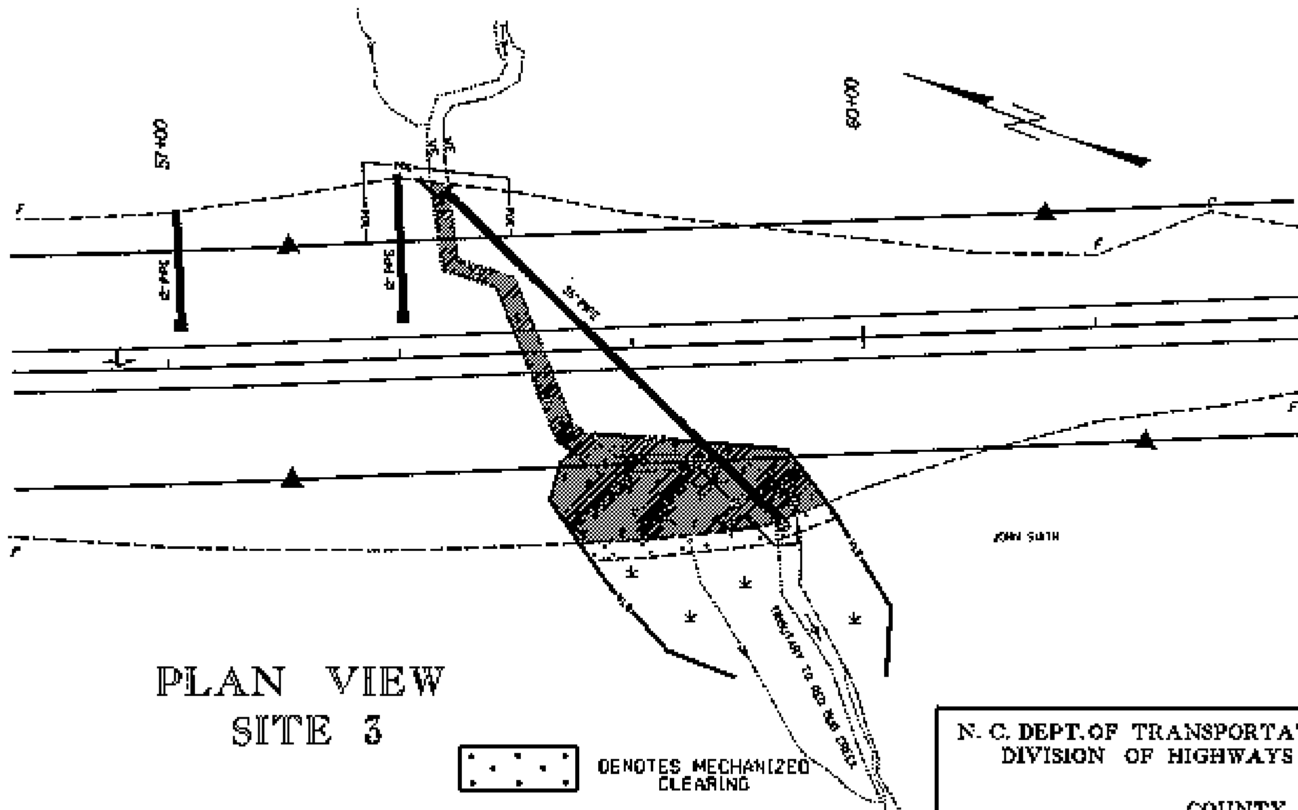
N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

________ COUNTY

PROJECT:

SHEET 6 OF 12 1/21/99

APPENDIX L




# PLAN VIEW
# SITE 3

DENOTES MECHANIZED CLEARING

DENOTES FILL IN WETLAND

DENOTES FILL IN SURFACE WATERS

25' 0 50'
SCALE

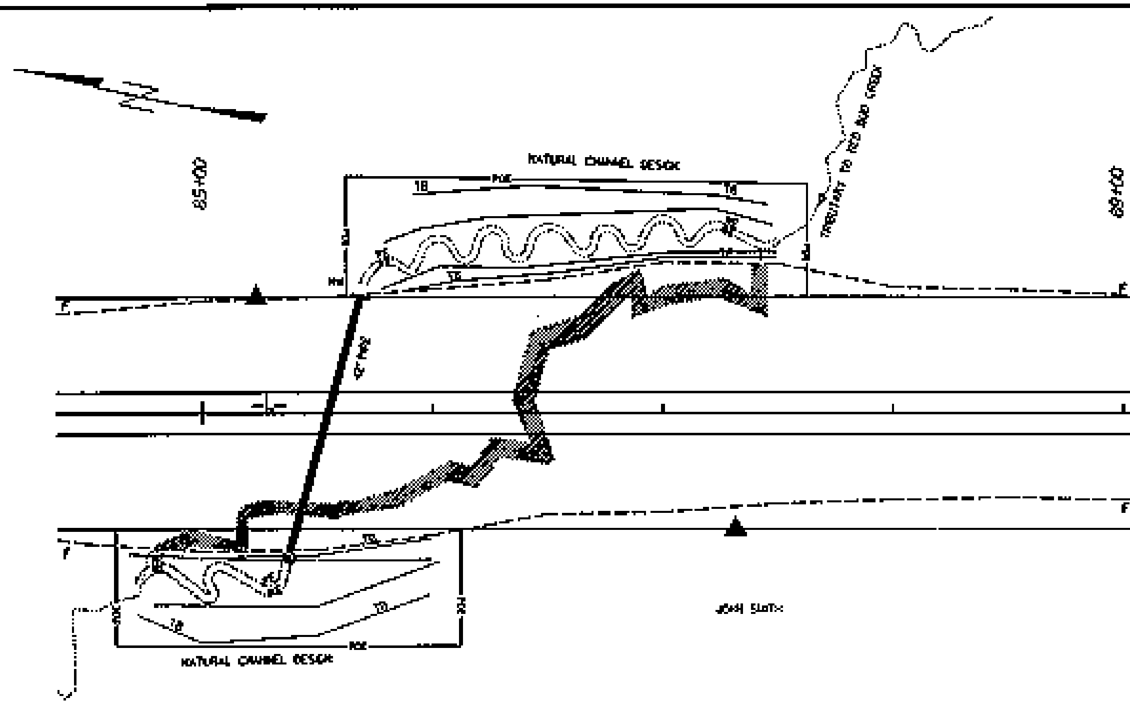
N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

COUNTY

PROJECT:

SHEET 7 OF 12 1/21/99

APPENDIX L




# PLAN VIEW
# SITE 4

25' 0 50' SCALE

DENOTES FILL IN SURFACE WATERS

N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

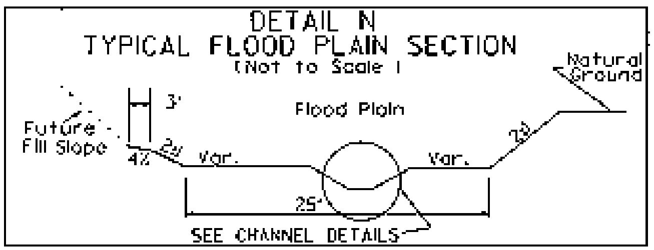
__________ COUNTY

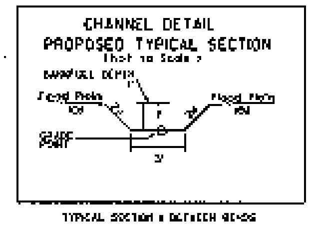
PROJECT:

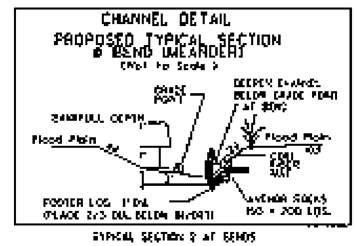
SHEET 8 OF 12 1/21/99

APPENDIX L

# NATURAL CHANNEL DESIGN TYPICALS




NOTES:

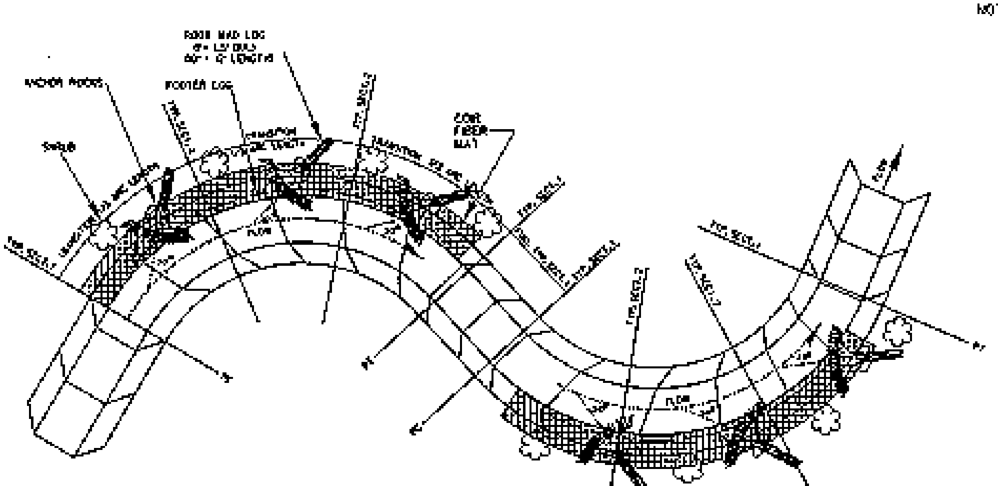
NUMBER OF ROOTWADS INSTALLED TO BE DETERMINED BY SITE

ROOTWADS TO BE SPACED 4x DIAMETER OF ROOT BASE

FOOTER LOG ANCHOR ROCK TO BE PLACED ON THE DOWNSTREAM END OF EACH FOOTER LOG SO THAT IT IS LEANING AGAINST THE LOG ON THE SIDE AWAY FROM THE CHANNEL.

WHEN BACKFILLING OVER AND AROUND FOOTER LOGS, ROOTWAD LOGS AND ANCHOR ROCKS FIRMLY SECURE ALL COMPONENTS INCLUDING JOINTS, CONNECTIONS AND GAPS.

PLANTINGS SHOULD BE PLACED ABOVE BANKFULL DEPTH



CHANNEL PLAN VIEW
SITE 4

N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

__________ COUNTY

PROJECT:

SHEET 9 OF 12 1/21/99

APPENDIX L

| ITEM | EXISTING STREAM | REFERENCE STREAM | PROPOSED RELOCATION |
|---|---|---|---|
| STREAM NAME | TRIB. RED BUD CK | TRIB. RED BUD CK* | TRIB. RED BUD CK |
| DRAINAGE AREA (DA) | 43 ac | 50 ac | 43 ac |
| CHANNEL SLOPE (S) | 1.57% | 1.0 % | .86% |
| BANKFUL WIDTH ($W_{bkf}$) | 6 ft | 10 ft | 8 ft |
| MEAN DEPTH ($d_{bkf}$) | 1.3 ft | 1.1 ft | 1.0 ft |
| BANKFUL X-SECTION AREA ($A_{bkf}$) | 7.5 $ft^2$ | 8.8 $ft^2$ | 7.5 $ft^2$ |
| WIDTH/DEPTH RATIO ($W_{bkf}/d_{bkf}$) | 4.6 | 9.1 | 8.0 |
| Maximum DEPTH ($d_{mbkf}$) | 2.0 ft | 2.3 ft | 2.0 ft |
| WIDTH Flood-Prone Area ($W_{fpa}$) | 6 ft | 22 ft | 24 ft |
| ENTRENCHMENT RATIO (ER) | 1.0 | 2.2 | 3.0 |
| CHANNEL MATERIALS: D50 | 4 inches | 3.5 Inches | 4 Inches |
| SINUOSITY (K) | 1.2 | 1.6 | 1.6 |
| MEANDERS: | | | |
| AVG. LENGTH | 33 ft | 35 ft | 33 ft |
| AVG. AMPLITUDE | 16 ft | 14 ft | 15 ft |
| AVG. RADIUS | 7 ft | 8 ft | 8 ft |
| DISCHARGES: | | | |
| Q BANKFULL | 20 cfs | 24 cfs | 20 cfs |
| Q2 | 21 cfs | 25 cfs | 21 cfs |
| Q10 | 44 cfs | 50 cfs | 44 cfs |
| VELOCITY: | | | |
| V BANKFULL | 3.1 fps | 2.7 fps | 2.6 fps |
| V2 | 3.4 fps | 2.8 fps | 2.7 fps |
| V10 | 4.4 fps | 3.5 fps | 3.4 fps |
| CLASSIFICATION | G3 | E3 | E3 |

* Tributary at Site 3

*STREAM DESCRIPTION AND CLASSIFICATION DATA SITE 4*

N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

________ COUNTY

PROJECT:

SHEET 10 OF 12 1/21/99

# PROPERTY OWNER

## NAME AND ADDRESS

| OWNER'S NAME | ADDRESS |
|---|---|
| (Example)<br>John Smith | P.O. Box 26201<br>Raleigh, NC 27611 |
| | |
| | |
| | |
| | |
| | |

N. C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

____________ COUNTY

PROJECT:

SHEET 11 OF 12 1/21/99

# IMPACT SUMMARY

| | | | WETLAND IMPACTS | | | | SURFACE WATER IMPACTS | | | | | | BUFFER IMPACTS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site No. | Station (From/To) | Structure Size | Fill In Wetlands (ha) | Temp. Fill In Wetlands (ha) | Excavation In Wetlands (ha) | Mechanized Clearing (Method III) (ha) | Fill In SW (Natural) (ha) | Fill In SW (Pond) (ha) | Temp. Fill In SW (ha) | Existing Channel Impacted (m) | Relocated Channel (m) | Enclosed Channel (m) | Zone 1 (ha) | Zone 2 (ha) |
| 1 | 30+35 | 30" PIPE | | | | | 0.01 | | | 82 | | 73 | | |
| 2 | 38+50 | 3@12'x9' BOX CULVERT | | | | | 0.03 | | | 104 | 43 | 60 | | |
| 3 | 58+90 | 36" PIPE | 0.08 | | | 0.02 | 0.05 | | | 239 | | 207 | | |
| 4 | 85+55 | 42" PIPE | | | | | 0.07 | | | 384 | 281 | 114 | | |
| TOTALS: | | | 0.08 | 0 | 0 | 0.02 | 0.16 | 0 | 0 | 809 | 324 | 454 | 0 | 0 |

N.C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

COUNTY

PROJECT:

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01/21/1999

# Stream Relocation Guidelines

NOTE: These guidelines are for the piedmont and coastal regions. While these guidelines are similar to the trout county requirements, they do not replace the existing process for trout counties. This guidance is to be followed **prior to the permit** process to facilitate that process and to minimize impacts

## "Minor Relocations"

**Applicable when:**

- Less than 100 feet of total relocation is required at a given crossing (from the end of the structure, inluding headwalls), and no more than 50 feet is relocated on any one side (upstream or downstream)

**Technical guidelines:**

-Relocation should be similar to original channel in

Width
Depth
Gradient
Substrate

-Bank vegetation should be re-established, but no specific planting regime is required

**Co-ordination with WRC field staff:**

-No coordination is required unless in High Quality Waters(HQW), critical habitat(as mapped by WRC), or at locations involving Federal/State listed species. Treat these cases as "Standard Relocations".

Note: WRC coordination will be welcomed even on "Minor"projects.

## "Standard Relocations"

**Applicable when:**

- Greater than 100 feet of total relocation is required at a given crossing (from the end of the structure inluding headwalls), Or more than 50 feet is relocated on any one side (upstream or downstream)

**Technical guidelines:**

-Relocation should be similar to original channel in

Width
Depth
Gradient
Substrate

**For the following items,** site specific requirements will be determined through coordination with the WRC field staff. These items will follow WRC's established guidelines and will incorporate any highway specific guidance jointly developed between WRC, Hydraulics, and Roadside Environmental:

- Re-etablishment of bank vegetation with planting regime required
- Meanders and habitat structures (root wads, wing deflectors, etc.) approximating the original stream

**Co-ordination with WRC field staff:**

-Coordinate the relocation with the appropriate WRC district fisheries biologist

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**General Guidance:** Minimize instream activities during peak spawning periods (April-June)

- Schedule instream activities during periods of low flow as much as possible
- Use vegetation to stabilize streambank vs. riprap to the maximum extent practicable
- Minimize use of fertilizer adjacent to stream
- Use native woody/shrub like species with small basal width within 25-50 ft. of the structure to reduce clogging. Beyond that distance use native tree species.
- It is preferred that bank vegetation be re-established prior to introducing flow into the channel.
- For reference utilize NC Wildlife Res. Comm. document "NC Stream Protection and Improvement Guidelines"

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NOTE: Coordination with WRC on projects covered by nationwide permits (outside the 25 trout counties) is **voluntary**. This is a proactive effort by NCDOT and WRC minimize habitat impacts from highway projects and to facilitate communication and understanding at the field level.

**STREAM CROSSING GUIDELINES**

**FOR ANADROMOUS FISH PASSAGE**

Anadromous Fish are a valuable resource and their migration must not be adversely impacted. The purpose of this document is to provide guidance to the North Carolina Department of Transportation to ensure that replacement of existing and new highway stream crossing structures will not impede the movement of Anadromous Fish.

**Applicable When:**

- Project is in the coastal plain defined by the "Fall Line" as the approximate western limit (see attached figure).
- For perennial and intermittent streams delineated on most recent USGS 7.5 minute quadrangle maps.

**General Guidelines:**

- Design and scheduling of projects should avoid the necessity of instream activities during the spring migration period. For the purposes of these guidelines "Spring" is considered to fall between February 15 and June 15. (In areas where the shortnose sturgeon may be present, the Cape Fear, Brunswick and Waccamaw Rivers, spring shall be defined as February 1 to June 15).
- Bridges and other channel spanning structures are preferred where practical.

**Technical Guidelines:**

- In all cases, the width, height and gradient of the proposed opening shall be such as to pass the average historical spring flow without adversely altering flow velocity. Spring flow should be determined from gage data if available. In the absence of this data, bankfull flow can be used as a comparative level. (Reference, "Fisheries Handbook of Engineering Requirements and Biological Criteria", Bell 1973, for fish swimming limitations.)
- The invert of culverts shall be set at least one foot below the natural stream bed.

- Crossings of perennial streams serving watersheds greater than one square mile shall provide a minimum of four (4) feet of additional opening width (measured at spring flow elevation) to allow for terrestrial wildlife passage.

- In stream footings for bridges will be set one foot below the natural stream bed when practical.

For crossing sites which require permit review the following information will be provided as a minimum to facilitate resource agency review.

- Plan and profile views showing the existing and proposed crossing structures in relation to the stream bank and bed.

- Average historical spring flow (or bankfull flow) for the site.

- How the proposed structure will affect the velocity and stage of the spring flow (bankfull).

- Justification for any variance from the guideline recommendations.

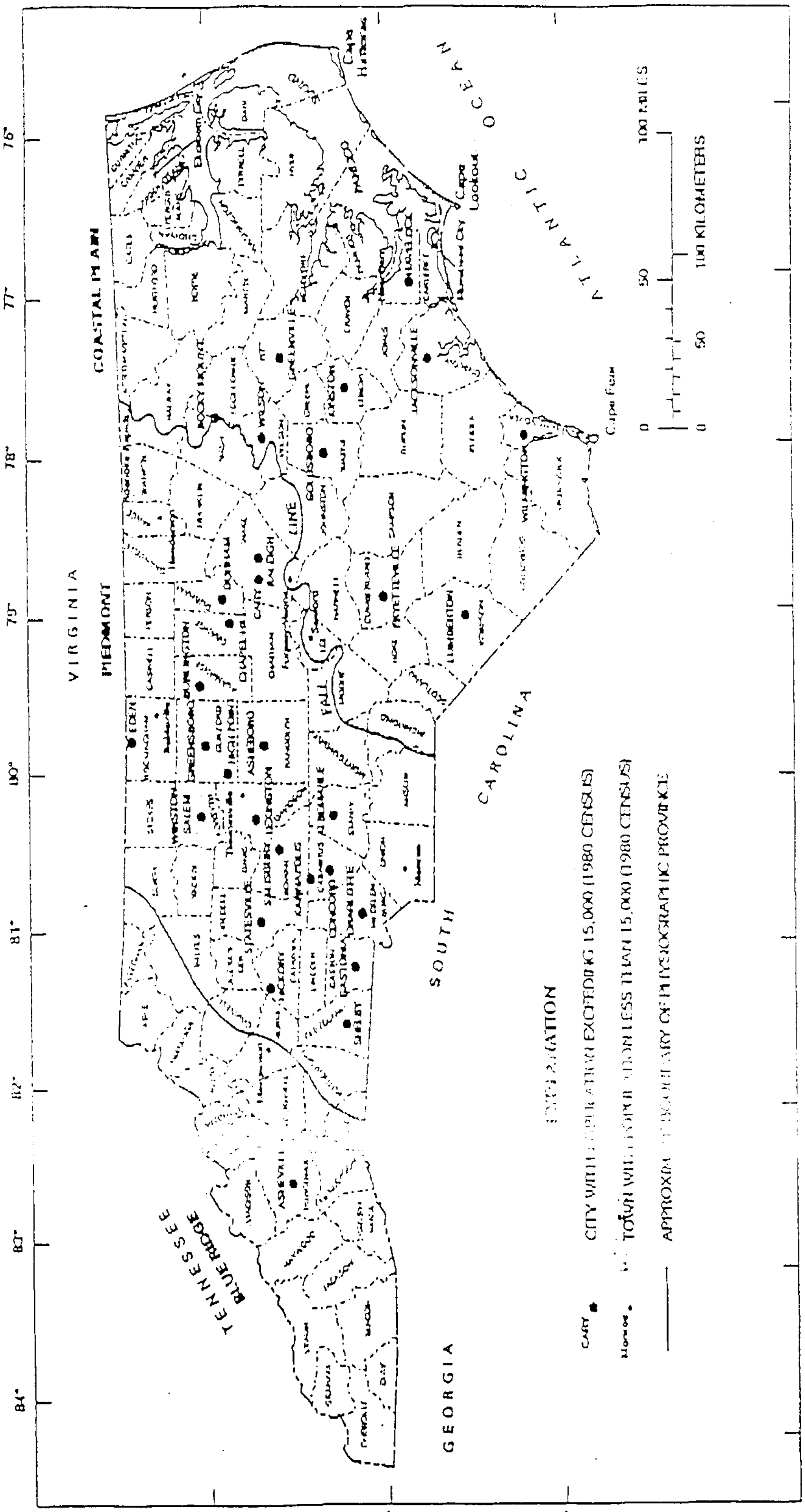


Figure 2. Counties and major population centers of North Carolina.

# GUIDELINES FOR THE LOCATION AND DESIGN OF HAZARDOUS SPILL BASINS

Hazardous Spill Basins are provided in new highway construction and major improvment projects at strategic locations along arterial system highways to aid in containment and clean up of accidental spills. The determination of these strategic locations is based on concentrated truck usage areas such as; parking sites at rest areas, weight stations, and runaway ramps, as well as for highway segments in close proximity to particularly sensitive waters such as; outstanding resource waters and water supply sources.

The strategy is to configure the highway segment of concern such that any potential spill runoff would be directed through a facility (basin) where the flow could be interrupted and temporarily stored to prevent hazardous material from reaching a receiving stream.

The use of these basins and other management practices to protect receiving waters is in accordance to the general policies and criteria presented in the departments document "Best Management Practices for Protection of Surface Waters". The following is additional specific guidance in the location and design of the basins:

<u>APPLICABLE LOCATIONS</u>

- Basins will be provided **at stream crossings** on highways functionally classified as a rural or urban arterials and,
    - The stream[(1)] is identified as an Outstanding Resource Water (ORW) or a WS-I watersupply, or
    - The stream[(1)] crossing is within 1/2 mile of the critical area[(2)] of a water supply source classified as WS-II, WS-III and WS-IV.
- Provision of basins at crossings of those streams on highways functionally calssified as collectors and local streets and roads can be evaluated on a site by site basis with consideration for:
  traffic volume, traffic type, accident potential related to the highway geometrics, receiving water quality, and the feasibility of basin construction at the site.

(1) *For the purpose of these guidelines "stream" will be defined as those depicted as blue lines on 7-1/2 minute (1:24000 scale) United States Geological Survey (USGS) quadrangles.*

(2) *Critical area is defined as extending 1/2 mile from the normal pool elevation of a reservoir; or 1/2 mile upstream of , and draining to an intake. This would make the effective area for hazardous spill basins placement, within 1.0 mile of the normal pool or upstream of an intake.*

## DESIGN REQUIREMENTS

- The volume of spill containment storage provided will be approximately 10,000 gallons plus the estimated runoff volume from a rainfall intensity equating to a two year return period event.

- A means will be provided such that the normal free flow of runoff at the basin outlet can be interrupted to cause containment of hazardous runoff. This can be accomplished by providing a mechanical control gate or by constructing a minimum control section in the outlet channel that could be readily blocked by such simple mean as shoveled earth material or stacked bags.

- The mechanical gate alternative will generally be utilized in areas where normal operational activities would allow close scrutiny and control, reducing the potential for problems with vandalism. Examples would be rest areas, weight stations and within controlled access.